CLIMATE CHANGE & MANAGEMENT OF RIVER, RIPARIAN, AND WETLAND HABITATS IN WYOMING

Summary from Wyoming Game and Fish Department Climate Change Workshop - April 28-30, 2020

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Executive Summary

In April 2020, the Wyoming Game and Fish Department (WGFD) held a workshop where WGFD managers could learn about the latest science on recent and future climate changes, and discuss the consequences of those changes for aquatic and terrestrial habitat management in the State. Focused on river, riparian, and wetland ecosystems, the workshop was designed to help managers consider the ways in which those habitats might be impacted by a changing climate, which types of watersheds and Wildlife Management Areas might be most vulnerable to climate change, and what management actions would be important to helping fish, wildlife, and plants cope with those impacts. Ultimately, results from the workshop were intended to inform and be incorporated into the 2020 revision of the Wyoming Statewide Habitat Plan.

The **workshop goals** were to:

- Learn about the best-available climate change projections and research on impacts to river, riparian, and wetland habitats in Wyoming;
- Explore the consequences of climate change for the WGFD Statewide Habitat Plan actions and priorities;
- Identify climate-informed habitat protection and restoration actions that could be taken in specific Wildlife Habitat Management Areas or watersheds; and
- Develop a list of data, information, and analyses that would be useful for making climate-informed habitat management decisions in the near- and longer-term.

Although climate change presents challenges to meeting management goals across all habitat types in Wyoming, this workshop was focused on river, riparian, and associated wetland habitats. Narrowing the focus this way allowed for greater specificity in workshop discussions while ensuring relevance to both the aquatic and terrestrial habitat components of the Statewide Habitat Plan. Several workshop breakout sessions focused on one of four focal geographies across the state: the Bear River watershed in southwest WY, the Horse Creek watershed in southeast WY, the Spence and Moriarty Wildlife Management Area (WMA) in central WY, and the Yellowtail Wildlife Habitat Management Area (WHMA) in north-central WY. These watersheds and management areas were selected to represent a diversity of ecosystems and to intersect several common management issues.

The interactive portion of the workshop included breakout discussions on:

- Climate change impacts of concern facing river, riparian, and wetland habitats,
- Factors that influence the relative climate change vulnerability of watersheds and wildlife management areas (WHMAs/WMAs) across the state,
- What's different about "climate-informed" habitat management for river, riparian, and wetland ecosystems,
- Priority climate-informed strategies for inclusion in the 2020 revision of the Statewide Habitat Plan, and
- Climate-related research and information needs.

Climate Change Impacts of Concern

Climate projections vary somewhat across the four focal geographies, but all climate models that were examined for this workshop agree that Wyoming will be significantly hotter by 2040-2069 relative to the baseline period of 1971-2000. Warming is projected to occur across all seasons, with annual increases ranging from approximately +3^{0}F to +8^{0}F, depending on the climate model and assumptions about future greenhouse gas emissions. Associated with that warming will be an increase in the number of extremely hot days with heat index > 90^{0}F, a longer growing season, and more growing degree days. Precipitation projections are more complicated and therefore less certain. However, a majority of climate models project that annual, winter, and spring precipitation will increase. Some climate models project decreases in summertime precipitation, although model agreement is medium-to-low and varies across the four focal geographies. Future projections for snow water equivalent (SWE) on April 1st vary across the four geographies, with Yellowtail WHMA and Bear River watersheds likely to see declines, Spence Moriarty WMA likely to see increases, and greater uncertainty for the Horse Creek watershed. Evapotranspiration is likely to increase at all locations in the spring and summer, with the exception of the Horse Creek watershed which may see declines in evapotranspiration in summer. Soil moisture is notably difficult to predict using climate models, but the models considered tend to suggest that soil moisture will increase in the spring and decrease in summer and fall. Other climate changes of note include high confidence that there will be increases in the intensity of precipitation events, springtime flooding, and future droughts; and rise in the elevation of mountain snowlines.

After reviewing the future climate projections, workshop participants identified more than 70 climate change impacts of concern related to the following aspects of river, riparian, and wetland ecosystems:

- Surface and groundwater availability (including quantity, quality, temperature, and timing),

- Physical stream conditions (including sedimentation and erosion),
- Aquatic habitat and species (including invasive aquatic species),
- Upland habitat and species (including invasive terrestrial species),
- Wetlands,
- Human water use (including irrigation).

With respect to hydrology, a common thread across the breakout groups surrounded the management implications of having to deal with both higher high flows and lower low flows, or greater fluctuations in stream flows across seasons and years. These hydrological changes could then lead to increasing rates of channel adjustments and erosion, which may render historical reference conditions less relevant when designing stream restoration projects. Biological impacts of concern to aquatic and terrestrial habitats include declines in some key habitats (e.g., for cold water fish such as cutthroat trout), shifts in species distributions (e.g., warmer-water fish moving upstream, and vegetation communities shifting upslope), and increases in the presence and abundance of invasive species. There was also a recognition that in addition to worrying about the direct effects of climate change on fish and wildlife and their habitats, it is also important to consider the "wild card" of how humans are responding to climate change. For example, climate changes will likely alter the timing and amount of water needed for irrigation, which could further limit water availability for fish, wildlife and plants.

Climate Change Vulnerabilities of Watersheds and Management Areas

Climate change vulnerability is defined as a function of a species' or area's exposure to changes in climate conditions (EXPOSURE), the sensitivity to those changes (SENSITIVITY), and the ability to cope with or respond to those changes (ADAPTIVE CAPACITY). An assessment of the relative vulnerability of watersheds or wildlife habitat management areas to the impacts of a changing climate can help target habitat protection and restoration efforts. Workshop participants identified a wide range of factors that might make a watershed or wildlife habitat management area relatively more or less vulnerable to the impacts of a changing climate on river, riparian, and wetland ecosystems, including:

Factors	Examples
Rate and magnitude of projected changes in climate	amount of warming, changes in precipitation, changes in snow water equivalent (SWE), timing of water availability, frequency of drought, elevational shifts in the snowline.
Physical conditions	geology, elevation, aspect, soils, size and shape of watersheds, amount of watershed above or below future snowline, topographic and geological diversity, presence of microclimates, stream basin connectivity (longitudinal, vertical, lateral, and temporal), presence or absence of barriers to movement
Ecological conditions	divergence from healthy condition, presence of invasive species, amount of vegetation cover, presence or absence of beaver activity, genetic diversity, presence of refugia
Hydrological conditions	amount of reservoir shoreline that could be exposed to lake level fluctuations, presence of wetlands, level of floodplain connectivity, soil water holding capacity, % of streams that are perennial/intermittent/ephemeral, whether the watershed is glacier-, snow-, or rain-fed
Water management	ability to manage water resources (via irrigation, reservoir operations), availability of water rights for instream use
Changes in disturbances	changes in pest outbreaks or wildfire regimes
Distribution and abundance of sensitive species	specialist species, species at the edge of their range, high vs. low species diversity
Land ownership	private versus public lands and the ability to do larger scale restoration efforts
Support and resources	funding and public support

What's Different About Climate-Informed Management

Building off of discussions about climate change impacts and vulnerabilities, workshop participants tackled the question: ***"What, if anything, might we need to do differently about our work to be effective in light of expected climate changes and impacts?"***

Breakout groups discussed how several core management strategies that are common to WGFD's work -- riparian habitat protection and restoration, stream restoration, fish passage and stream connectivity, and water management -- might need to be modified in order to be effective in a changing climate, and identified strategies that may not necessarily need to be different, but which were flagged as being particularly important or urgent to address climate change impacts.

Climate-Informed Modifications to Current Practices:	Strategies and Actions With Increased Priority and/or Urgency:
• Design projects under the assumption of increasing likelihood of higher high flows, lower low flows, and more frequent extreme flood events, rather than historic or current hydrological conditions. • Use plant species or genetic stock that is more likely to thrive under future climate conditions in restoration projects. • Craft restoration and connectivity projects with future species' ranges and habitat conditions in mind. • Take climate change into account when prioritizing projects and articulating project goals. • Increase flexibility around water management and habitat restoration to address new problems that will need new solutions.	• Increased importance of retaining and conserving water. • Increased importance of securing and managing water rights. • Increased importance of riparian restoration and protection. • Greater urgency for landscape-scale conservation and management.

Priority Climate-Informed Actions for the Statewide Habitat Plan

Workshop participants identified over 75 habitat management actions that could help to address climate change impacts on river, riparian, and wetland habitats in Wyoming. There was a great deal of emphasis on actions relating to water availability and use. Nearly 20% of the identified actions related to water rights, water storage, water management, and irrigation. Strategies that the identified habitat management actions support include:

- Managing land and water use with an eye towards future conditions.
- Building watershed health and resilience to a changing climate.
- Maintaining species diversity and habitat needs in a changing climate.
- Making climate-informed decisions about angling, trapping, and setting goals for habitat management areas.
- Prioritizing habitat management efforts using a climate change lens.
- Establishing and implementing monitoring methods and protocols that can help to anticipate changes and set climate-informed priorities.

Information and Research Gaps

The final session of the workshop was dedicated to gathering participants' input on: ***What does the Agency need to know in order to make better climate-informed decisions in the next 5 years?***

In response, participants identified a large number of research questions, data products, and inventories that could help support climate-informed management decisions for river, riparian and wetland habitats. Workshop organizers combined similar topics from this discussion into a refined list of 44 information needs related to several themes, including: riparian and wetland ecosystems; aquatic habitat and fisheries; beaver and other process-based restoration approaches; assessments of climate change vulnerability, refugia, and prioritization/planning; invasive species; fish passage and stream connectivity; hydrology and water balance; stream restoration; water management; and baseline data and monitoring.

Following the workshop, we asked WGFD staff how useful each of the identified information needs would be to their ability to consider climate change effects on their work on river, riparian, and wetland habitats. Eight (8) of the information needs identified during the workshop were rated as being "Useful" or "Very Useful" by over 60% of survey respondents. These include efforts to identify important places for habitat management actions, such as streams that may become more (or less) suitable for particular fish species under a changing climate, or areas of "climate refugia" for imperiled species. They also include research designed to support our understanding of the effects of particular climate-informed management actions, such as the influence of process-based restoration approaches on water availability for downstream users, or how upland habitat treatments affect watershed hydrology under more intense precipitation events, or what are the tradeoffs and benefits of different water management approaches in a changing climate (e.g., flood vs. pivot irrigation, or managing water for instream vs. out-of-stream habitats). Lastly, they include information needs related to invasive species, such as which invasive species might be expected to increase or arrive in Wyoming as the climate changes, and what are the best management strategies for disadvantaging invasive plant and fish species.

Next Steps

The April 2020 Climate Change Workshop represented a valuable step in advancing WGFD staff's consideration of climate change in their habitat management work. Next steps to apply and build on the discussions at the workshop include:

- Incorporating climate-informed habitat management strategies into the 2020 Statewide Habitat Plan revision.
- Sharing this report within WGFD via a dedicated webpage, and formal and informal presentations.
- Presenting a summary of workshop discussions and products to the Wyoming Game and Fish Commission.
- Considering organizing similar climate change discussions within WGFD focused on additional regions, ecosystem types, or WGFD programs.
- Exploring research partnerships to focus on some of the high priority information needs identified by WGFD staff.
- Sharing methods and results from this project with other natural resource managers interested in making climate-informed management decisions.

Introduction

In 2020, the Wyoming Game and Fish Department (WGFD) began revising its Statewide Habitat Plan (SHP). The SHP articulates priorities for protection and enhancement of aquatic and terrestrial habitats across the state, and influences how the WGFD allocates annual funds. Since the SHP was last revised in 2015, WGFD managers have become increasingly concerned with how recent and potential future changes in climate could influence their management goals and actions. In response, habitat management leadership within the Department decided to hold a workshop where WGFD managers could learn about the latest science on recent and future climate changes, and discuss the consequences of those changes for aquatic and terrestrial habitat management in the State. Initially focused on climate change impacts and management responses in river, riparian, and wetland ecosystems, the workshop was intended to provide WGFD staff with access to information and approaches for climate-informed planning that could also support management thinking in other habitat types. Workshop sessions were designed to help managers consider the ways in which river, riparian, and wetland habitats might be impacted by a changing climate, which types of watersheds and Wildlife Management Areas might be most vulnerable to climate change, and what management actions would be important to helping fish, wildlife, and plants cope with those impacts. Ultimately, results from the workshop were intended to inform and be incorporated into the 2020 SHP revision.

Workshop Details

Workshop Goals and Desired Outputs

The **workshop goals** were to:

- Learn about the best-available climate change projections and research on impacts to river, riparian, and wetland habitats in Wyoming;
- Explore the consequences of climate change for the WGFD Statewide Habitat Plan (SHP) actions and priorities;
- Identify climate-informed habitat protection and restoration actions that could be taken in specific Wildlife Habitat Management Areas or watersheds; and
- Develop a list of data, information, and analyses that would be useful for making climate-informed habitat management decisions in the near- and longer-term.

The **desired outputs** included:

- A report that summarizes workshop discussions (this report);
- A list of specific strategies and actions that could be incorporated into the draft revision of the Statewide Habitat Plan (see Summary Results section of this report);
- A list of information needs (e.g., research, analyses, products, inventories) that could be the focus of new research and partnerships involving WGFD and outside climate change experts (see Summary Results section of this report).

Focus on River, Riparian, and Wetland Habitats

Although climate change presents challenges to meeting management goals across all habitat types in Wyoming, we chose to focus this workshop on river, riparian, and associated wetland habitats. Narrowing the focus allowed for greater specificity in workshop discussions, while ensuring relevance to both the aquatic and terrestrial habitat components of the Statewide Habitat Plan. The focus also coincides with widespread concerns about the impacts of climate change on the management of freshwater, riparian, and wetland ecosystems among State fish and wildlife management agencies in the North Central region (Montana, Wyoming, Colorado, North Dakota, South Dakota, Nebraska, and Kansas) (Crausbay and Cross 2019). During workshop discussions, we considered future climate conditions that are projected for the time period 2040-2069. This time period was chosen because of the availability of future climate projections for those years, and because it was considered relevant to thinking about the implications of climate change on management actions being taken in the coming years, that are expected to have long-lasting effects on the provision of habitat for wildlife.

Workshop Format

The workshop was designed to follow common steps in proactive climate change adaptation planning (also referred to as “climate-smart conservation planning” or “climate-informed management planning”). A number of step-wise approaches to climate change planning exist (e.g., Cross et al. 2013, Stein et al. 2014, Swanston et al. 2016). These approaches share many similarities, including that they are:

- **Iterative** - by embracing an iterative plan-act-evaluate approach that allows for active learning and adjustments to account for new information or changing conditions.

- **Participatory** - by encouraging climate experts and natural resource managers to work together through the planning steps, so that the best-available information is considered and climate experts can learn about the types of information that are most useful to decision making.
- **Designed to generate specific adaptation options** - by bringing a level of specificity to discussions about climate change impacts and potential management responses that can be directly useful to managers.

The core steps in proactive climate change adaptation planning include assessing climate change impacts and vulnerabilities, reviewing and revising management goals in light of climate change impacts, and identifying adaptation options - or climate-informed management actions to help species and ecosystems adapt to a changing climate. Therefore, we designed the WGFD workshop to align with these steps and provide an opportunity for fish, wildlife and habitat managers to contemplate a series of questions about their work, including:

Will climate change alter the effectiveness of current actions?

Are new actions needed to achieve goals as climate changes?

Do management goals need to change?

Initially planned as an in-person workshop, organizers converted the workshop to a virtual format once it became clear that it would not be possible to meet in person during the COVID 19 pandemic. We chose Zoom as our video-conferencing program, due to its robust capabilities for all of the plenary and breakout sessions. We used shared, live-editable Google Docs to capture individual contributions and group discussions during breakout sessions. The workshop agenda (Appendix A) started on Day 1 with a ~2-hour panel of climate science presentations that served to summarize the best-available information on observed climate changes across Wyoming, modeled future climate changes in the state, and potential impacts on snowpacks, streamflows, fisheries, and wetlands (a recording of the Day 1 climate science webinar and all presentations from the workshop are available upon request from mcross@wcs.org; WGFD staff can access workshop materials on the internal WGFD website at: https://gfi.state.wy.us/ClimateChangeWS/index.asp). The interactive workshop portion started on Day 2 and continued into Day 3, with ~2-hour sessions in both the morning and afternoon. Each session included a brief plenary presentation on key concepts followed by interactive breakout discussions on topics such as:

- Climate change impacts on river, riparian, and wetland habitats & consequences for the Statewide Habitat Plan.
- Assessing relative climate change vulnerability of watersheds and Wildlife Habitat Management Areas (WHMAs) across the state.
- What's different about "climate-informed" habitat management for river, riparian, and wetland ecosystems.
- Priority climate-informed strategies for inclusion in the 2020 revision of the Statewide Habitat Plan.
- Climate-related research and information needs for the Statewide Habitat Plan revision and beyond.

For the breakout discussions on climate change impacts and priority climate-informed strategies for inclusion in the 2020 SHP revision, we chose to focus on four different geographies across the state: the Bear River watershed in southwest WY, the Horse Creek watershed in southeast WY, the Spence and Moriarty Wildlife Management Area in central WY, and the Yellowtail Wildlife Habitat Management Area in north-central WY (Figure 1). These watersheds and management areas were selected to span the state and intersect several common management issues. Identifying widely separated areas across the state was desired to effectively engage and generate interest with the habitat biologists that would be the primary audience for the workshop. Reasons for selecting these specific locations included:

- The Bear River watershed is one of the six watersheds identified in Wyoming's State Wildlife Action Plan, meaning that results from the workshop could be directly relevant to future iterations of that plan. Also, this watershed in southwest Wyoming is relatively small which allows for focused analysis. Finally, the Bear River basin has been a recent focal point and area of interest for a group of conservation partners led by the Intermountain West Joint Ventures Water 4 Initiative.
- The Horse Creek subwatershed in SE Wyoming was selected as a representative of a prairie stream ecosystem that harbors high fish diversity and species of greatest conservation need.
- The Spence Moriarty WMA was selected as a place under WGFD management that is relatively high elevation, harbors cutthroat trout, has extensive riparian habitat, and involves heavy irrigation practices. Climate change will likely have significant implications for influencing trade offs between hay production from irrigated meadows and fish production and survival in extensive stream environments.
- The Yellowtail WHMA was identified as a relatively low elevation management property that contains extensive wetlands, diversion and irrigation from a major river, farmed fields, and extensive riparian habitat. Issues of water management at this property would be relevant to other management properties held by the Wyoming Game and Fish Commission across the state.

Participants

Most workshop participants were WGFD staff, from across regions and divisions within the Department (Appendix A). Participants included regional terrestrial and aquatic habitat biologists, habitat and access biologists, fish management biologists, fish and wildlife managers, and a deputy director. Several external climate experts from the US Geological Survey, University of Wyoming, University of Colorado-Boulder, North Central Climate Adaptation Science Center, Wildlife Conservation Society, and The Nature Conservancy participated in portions of the workshop. The number of individuals participating in the workshop varied from approximately 35 to 65, depending on the session.

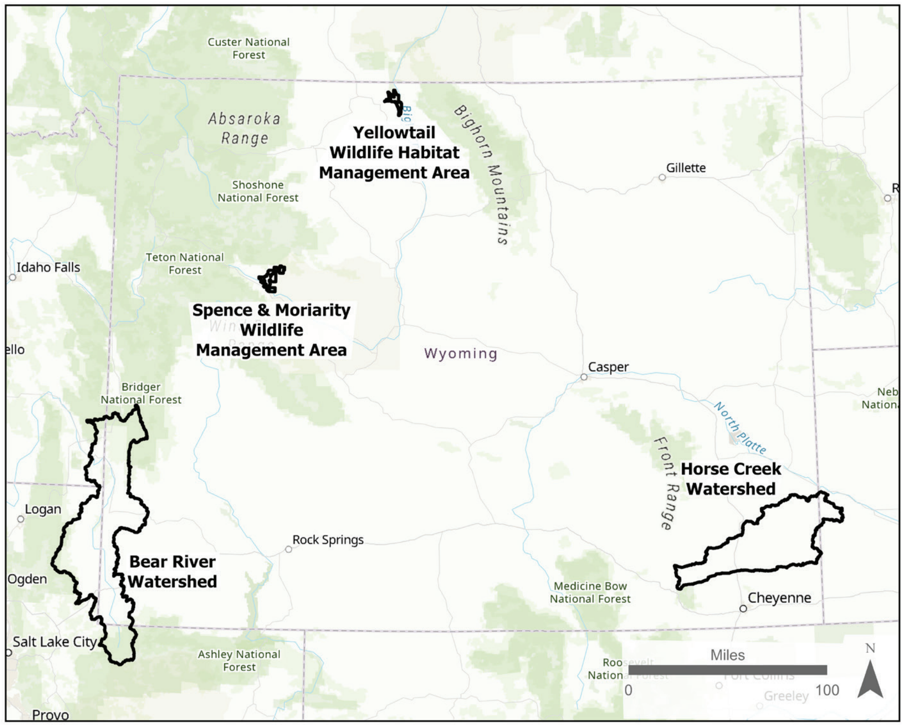

Figure 1. Map of Wyoming highlighting the four watersheds or management areas that were the focus of workshop discussions.

Applying the Workshop Approach to Additional Topics

As described in more detail in the following sections of this report, we developed a set of worksheets to guide workshop participants' discussions for each step in the climate change planning process. **This collection of worksheets can serve as a discussion guide for future workshops focused on other ecosystems, properties, species, or habitat types of relevance to WGFD or other agencies and decision makers.** Therefore, we have included blank versions of the worksheets (Appendix B) that could be used to help guide discussions during future workshops.

Summary of Results

Climate Change Impacts of Concern

Drawing on the climate change information shared during the Day 1 presentations and a worksheet that summarized future climate model projections (Table 1), workshop participants discussed the ecological consequences of those changes in climate for river, riparian, and wetland ecosystems. Future climate projections for the period 2040-2069 were summarized for each of the four focal geographies by Dr. Imtiaz Rangwala (University of Colorado-Boulder and the North Central Climate Adaptation Science Center), using climate model outputs downloaded from the ClimateToolbox (Table 1).

Climate projections vary slightly across the focal geographies, but all climate models that were examined for this workshop agree that Wyoming will be significantly hotter by 2040-2069 relative to the baseline period of 1971-2000 (Table 1). Warming is projected to occur across all seasons, with annual increases ranging from approximately +3^{0}F to +8^{0}F, depending on the climate model and assumptions about future greenhouse gas emissions. Associated with that warming will be an increase in the number of extremely hot days with heat index > 90^{0}F, a longer growing season, and more growing degree days. Precipitation projections are more complicated and therefore less certain. However, a majority of climate models project that annual, winter, and spring precipitation will increase. Some climate models project decreases in summertime precipitation, although model agreement is medium-to-low and varies across the four focal geographies. Future projections for snow water equivalent (SWE) on April 1st vary across the four geographies, with Yellowtail WHMA and Bear River watersheds likely to see declines, Spence Moriarty WMA likely to see increases, and greater uncertainty for the Horse Creek watershed. Evapotranspiration is likely to increase at all locations in the spring and summer, with the exception of the Horse Creek watershed which may see declines in evapotranspiration in summer. Soil moisture is notably difficult to predict using climate models, but the models considered tend to suggest that soil moisture will increase in the spring and decrease in summer and fall. Other climate changes of note include high confidence that there will be increases in the intensity of precipitation events, springtime flooding, and future droughts; in addition to a rise in the elevation of mountain snowlines.

Table 1. Summary of climate change projections for Yellowtail Wildlife Habitat Management Area[1] (climate change projections for other focal geographies can be found in Appendix C).

Climate/ Hydrological Variable	Future Projected Changes *2040-2069 relative to 1971-2000* Range Across All Models & Emissions Scenarios	Mean for Moderate Emissions Scenario (RCP 4.5)	Mean for High Emissions Scenario (RCP 8.5)	Model Agreement[2]
Mean Temperature (°F)	Annual .... +3 to +8°F Winter........ +3 to +8°F Spring........ +3 to +8°F Summer ...... +4 to +8°F Fall.......... +3 to +7°F	+4.6°F +4.5°F +4.5°F +4.9°F +4.3°F	+6.1°F +5.8°F +5.7°F +6.7°F +6.1°F	All models project increases
Days w/ Heat Index > 90°F *(2 days/year historically)*	Increase to a Total of 6 to 19 days/year	+9 days	+13 days	All models project increases
Precipitation (%)	Annual .... -2 to +15% Winter........ 0 to +20% Spring........ 0 to +25% Summer ..... -15 to +10% Fall......... -5 to +20%	+6% +10% +13% -5% +8%	+9% +15% +16% -1% +9	High (+) High (+) High (+) Medium (-) Medium (+)
Growing season length (# days) *(historically 74 days)*	Longer growing seasons (+15 to +74 days longer)	+41 days	+52 days	All models project increases
Growing Degree Days (°F) *(historically 4200°F)*	Increase in growing degree days (Total of 4700°F to 6250°F)	5080°F	5780°F	All models project increases
April 1 Snow Water Equivalent (%)	Decreased SWE (-28% to -7%)	-14%	-19%	High (-)
Evapotranspiration (%)	Spring....... +20 to +52% Summer ..... +2 to +10% Fall......... +9 to +23%	+28% +5% +13%	+38% +6% +18%	High (+) High (+) High (+)
Soil Moisture (%)	Spring........ +2 to +12% Summer ...... -12 to -4% Fall.......... -11 to -5%	+6% -7% -7%	+8% -9% -8%	High (+) High (-) High (-)
Intensity of precipitation events	High confidence for increases in the intensity of precipitation events, particularly the hourly precipitation rate at 3-7% per 1°F warming.			
Flood frequency	High confidence for increases in springtime flooding (from increases in precipitation, increases in precipitation intensity, and rain on snow events).			
Drought	High confidence for increases in the intensity of future droughts; Propensity for increases in flash droughts (wet to dry in matter of weeks if there is a gap in precipitation).			
Mountain Snowline	High confidence it will move up. 250 ft upward shift for every 1oF warming.			

[1] Projected changes in climate and hydrological variables by 2040-2069 relative to 1971-2000 are obtained from the Climate Toolbox;
[2] Model agreement (an indicator of certainty level) = High (+) or High (-) (majority of models show increases or decreases); Medium (+) or Medium (-) (more than half the models show increases or decreases); Low (about equal number of models show increases or decreases).

After reviewing the future climate projections, workshop participants identified a range of climate change impacts of concern related to the following aspects of river, riparian, and wetland ecosystems (see Table 2 for details):

- Surface and groundwater availability (including quantity, quality, temperature, and timing),
- Physical stream conditions (including sedimentation and erosion),
- Aquatic habitat and species (including invasive aquatic species),
- Upland habitat and species (including invasive terrestrial species),
- Wetlands,
- Human water use (including irrigation)

With respect to hydrology, a common thread across the breakout groups surrounded the management implications of having to deal with both higher high flows and lower low flows, or greater fluctuations in stream flows across seasons and years. This also included challenges posed by larger and more frequent floods, and increasingly severe droughts. Biological impacts of concern to aquatic and terrestrial habitats include declines in some key habitats (e.g., for cold water fish such as cutthroat trout), shifts in species distributions (e.g., warmer water fish moving upstream, and vegetation communities shifting upland), increases in the presence and abundance of invasive species, and increases in toxic algal blooms.

Breakout groups identified increasing physical changes to stream channels as a concerning factor. Natural channel design approaches to stream restoration are based on understanding historic reference conditions created under a certain climatic regime. A changing climate, many participants pointed out, will result in increasing rates of channel adjustments and erosion, and may render historical reference conditions less relevant.

There was also a recognition that in addition to worrying about the direct effects of climate change on fish and wildlife and their habitats, it is also important to consider the "wild card" of how humans are responding to climate change. For example, climate changes will likely alter the timing and amount of water needed for irrigation, which could further limit water availability for fish, wildlife and plants. There was also a consistent recognition of the importance of coordinating with other stakeholders and decision makers in the landscape, since WGFD only has direct control over some aspects of these ecosystems, especially with respect to water management.

Table 2. Climate change impacts of concern to river, riparian, and wetland ecosystems in Wyoming (summary across all four geographic breakout groups)

Category	Climate Change Impacts
Surface- and ground-water (quantity, quality, temperature, timing)	• Precipitation is expected to increase, but timing and form of precipitation will affect timing and quantity of water availability and in-stream flows: - Higher high flows and lower low flows. - Changes in timing of floods. - Accelerated snowmelt and shifts in spring flooding result in earlier peak hydrograph and reduced amount of water during the summer. - Increase risk of streams going dry - Some reaches may go dry during base flow. - Increased precipitation could lead to higher base flows and lateral habitat connectivity. - More variability in flows, with impacts on seasonal habitat availability. • Increased evapotranspiration - Suggests the offsetting of any increases in precipitation and further stresses on reduced water supplies. • Change in flood recurrence interval will change bankfull discharge, with consequences for the design of stream restoration projects. • Increased water temperature may lead to eutrophic impacts or algal blooms in reservoirs. • Increased temperatures combined with potential increased nutrients from fine sediment, could lead to increases in harmful algal/cyanobacterial blooms on lakes. • Changes in groundwater recharge, especially for groundwater recharge that is influenced by evapotranspiration.

Physical stream conditions, sediment, erosion	• Physical changes to stream channel morphology: - Increased flooding could lead to more frequent channel migration. - More spring runoff leads to more scouring of streams and movement of banks/channels. - Channel adjustments and plant establishment out of sync could lead to instability. • Increased frequency of intense precipitation events could lead to: - Increase in overland erosion and fine sediment transport, scour, and deposition; leading to increased sedimentation in rivers, streams, deltas, reservoirs, and wetlands. - Stream bank erosion - places that are currently eroding will have even more pressure on the banks, riparian areas, etc. - Flooding • Loss of flood flows needed to transport sediment loads and promote stable channels. • Increased evaporation and possible increase in reservoir water level fluctuations could make soils increasingly saline.
Aquatic habitat and species (including invasive species)	• Changes in community composition and species distribution: - Warmer stream temperatures may allow other species to move in - including increased invasion by non-native fish (e.g., rainbow and brook trout), supplanting native fish or increasing hybridization risk (e.g., yellowstone cutthroat trout). - Lower base flows, warmer water temps, limiting Bonneville Cutthroat Trout habitat. - Yellowstone Cutthroat Trout may move upstream into currently fish-less streams. - Fish may need access to thermal refugia and connectivity for them to be able to access those refugia (e.g., cooler tributaries, streams with spring inputs, deeper pools, more shade). • Impacts on growth: - Longer growing seasons may allow for greater overall growth rate (especially for cold-limited species) and the ability to compensate for metabolically stressful periods (as long as warming isn't severe enough to result in mortality). - Reduced streamflows lead to increased density and lower growth of trout (drift feeders). - Lower base flows, particularly late summer/fall could lead to reduced fish abundance and biomass, and reduced recruitment. • Impacts on fish health and mortality: - Days with heat index >90 could be a potential trigger point for mortality, especially if combined with low flow and low oxygen levels. - Duration of temperature extremes are important - many fish species can handle stressors of warmer temps but not for long durations. - Increased susceptibility to disease (e.g. gill lice). • Loss of synchrony: - Biota are adapted to particular patterns of synchrony - With changes in timing and delivery of water, location of water availability, we expect a loss of synchrony -- but we don't know how to anticipate the real effects of this loss of synchrony. • Impacts on spawning: - Earlier spawning. - Increased sediment runoff, particularly in spring months, could negatively impact fish spawning and egg survival in riverine species above and below the dam. • Impacts from changes in water management (irrigation, diversions, reservoirs): - Increased potential for upstream irrigation dam and infrastructure failures that may degrade aquatic habitats. - Less flood irrigation could equate to less entrainment of fishes. - Reduced stream flows could lead to more instream manipulation for water withdrawal, and further reduced connectivity for fish and increased entrainment of fishes. - Source water temperature at diversions could be significantly increased due to irrigation return flows and warming/eutrophication, which could result in fish kills.

Upland habitat and species (including invasive species)	• Impacts to riparian vegetation: - Longer growing season could provide some benefits to plant growth, but less soil moisture, increased evaporation, and drought could decrease plant growth and degrade riparian areas. - Earlier snowmelt in the spring could affect reproduction of cottonwood and willows that are adapted to set seed and germinate later (Disrupted phenology). - Sediment transport could affect cottonwood recruitment. - Interaction of early season flooding and late season drought may negatively impact persistence of woody plants, leading to domination by herbaceous plants. • Impacts to upland habitats: - Upward elevation shifts in snowline could affect aspen recruitment and increase loss of aspen to conifers. - Drought and decreases in water in uplands will encourage congregations of wildlife (and possibly cattle), which could promote erosion. - Changes in the amount and quality of forage for ungulates. - Longer growing seasons and reduced upland vegetation production may lead to a greater reliance on irrigated meadows. • Increase in invasive species: - E.g., Cheatgrass and other undesirable annual grasses, tamarisk, Russian olive. - Earlier warm-up may allow for invasive annuals to get an even earlier start and foothold. - Warming will increase noxious weed treatments and require additional time to treat. - Greater uncertainty in water supply and potentially larger fluctuations in reservoir levels could result in opportunities for generalist riparian vegetation invasions. - Native junipers could outcompete riparian vegetation. - Consequences of increased invasive species include increased fire (especially with cheatgrass) and habitat loss. • Impacts to watershed function: - Increased flooding may blow out beaver dams. - Reduced summer soil moisture spells need for beefing up "sponges" via more intact wetlands, riparian plantings particularly in agricultural areas. • Changes in disturbances: - Longer and more intense fire season, higher fuel loads (due to increased vegetation growth from increased precipitation and longer growing season). - Increased grass density-combined with intensity of drought may lead to grass fires. - Changes in insects and diseases affecting plants (e.g., pine beetle). - Wet springs with hot dry summers may equate to increased grasshoppers. • Impacts to terrestrial wildlife: - Increase in very hot days could affect ungulates. - Upward shifts in snowline could lead to changes in use pattern for large carnivores (i.e., bears and moth sites) and ungulates (that are following spring green-up). - Increase in hot days and rapid rise and fall of ponds and reservoirs could lead to some wetland complexes drying out, placing stress on avian nesting and potential nest failures. - Increased growing season and growing degree days could shift the phenology of plants, leading to mismatched timing of pollination, insect abundance, and migrating wildlife (including birds).
Wetlands	• Loss of ability to flood irrigate could reduce wetlands. • Climate changes could lead to certain wetland complexes drying out. • Shallower wetlands and the loss of surface water in wetlands in late summer could lead to a lack of habitat or even sinks for waterfowl and amphibians. • Increases in fine sediment contributions could lead to wetland creation at reservoir margins.

Human water use (including irrigation)	• Increased water uses and changes in timing - Increased temperature, lower water availability, longer growing season, and increased aridity means greater demands for water, especially by agricultural water users but also for habitat management. - Need for irrigation earlier and later in season, and more often. - Changes in agricultural practices could lead to greater water demand - e.g., changes in crop type, longer growing season could increase potential for additional hay production or multiple crops in a season. • Impacts to water supply and changes in timing: - Reduced snow-water equivalent (SWE) could lead to reduced water availability for irrigation and wetland/pond complexes, having a negative impact on wildlife. - Decreased snow-water equivalent (SWE), declines in summer precipitation, and higher need for summer irrigation will lead to more frequent and longer duration of extreme low flows (e.g., flash droughts). - Loss of reliable streamflow may encourage more water storage developments (e.g., adding reservoirs, holding ponds), which could increase water temperatures or result in decreased in-stream flows. • Changes in agricultural practices: - Increased spring moisture could delay crops from being planted and increase flooding. - Unclear tradeoffs between flood irrigation (which has return flow benefits) vs. pivot irrigation (which is seen as more efficient but uses water in different ways). - Changing agricultural intensity or crop types will impact the availability (timing, quantity) of water for conservation • Human responses to climate change: - It is not just the direct effects of climate change, but the wild card of how humans are also responding to climate change (e.g., via different irrigation patterns, livestock patterns, human development patterns, etc). • Impacts to irrigation infrastructure: - Increased flooding could impact instream/inditch infrastructure. - Increased sedimentation could increase the need for maintenance of irrigation systems.

Climate Change Vulnerability of Watersheds and Wildlife Habitat Management Areas

Climate change vulnerability is often defined as a function of a species' or area's exposure to changes in climate conditions (EXPOSURE), the sensitivity to those changes (SENSITIVITY), and the ability to cope with or respond to those changes (ADAPTIVE CAPACITY). An assessment of the relative vulnerability of watersheds or wildlife habitat management areas to the impacts of a changing climate can help target habitat protection and restoration efforts. For example, areas of relatively high climate change vulnerability might be places where protection or restoration actions that reduce the exposure or sensitivity to climate change, or increase the adaptive capacity for coping with climate change impacts, may be necessary. Areas of relatively low climate change vulnerability might be places where proactive protection efforts could retain valued species or habitat characteristics that are currently found in those places, even as the climate changes.

Following an introductory presentation on core concepts of climate change vulnerability, workshop participants identified a wide range of factors that might make a watershed or wildlife habitat management area relatively more or less vulnerable to the impacts of a changing climate on river, riparian, and wetland ecosystems (see Appendix C for completed worksheets from each breakout session). Tables 3 and 4 summarize the potential measures of relative exposure, sensitivity, and adaptive capacity that were identified across all four breakout discussions. Table 3 captures vulnerability measures for watersheds; Table 4 captures vulnerability measures for wildlife habitat management areas (WHMAs).

Factors that could lead to relatively higher or lower **EXPOSURE** of watersheds or WHMAs to climate change included:

- **Rate and magnitude of projected changes in climate** - e.g., amount of warming, changes in precipitation (including the proportion of precipitation falling as rain vs. snow), changes in snow water equivalent (SWE), timing of water availability, frequency of drought, elevational shifts in the snowline.
- **Physical conditions** - e.g., geology, elevation, aspect, soils, watershed size.
- **Current ecological/hydrological conditions** - e.g., amount of reservoir shoreline that could be exposed to lake level fluctuations.
- **Current water management** - e.g., Areas where water management is already intense could have increased exposure to water limitations.
- **Changes in disturbances** - e.g., changes in pest outbreaks or wildfire regimes.

Factors that could lead to relatively higher or lower **SENSITIVITY** of watersheds or WHMAs to climate change included:

- **Distribution and abundance of sensitive species** - e.g., specialist species, species at the edge of their range, high vs. low diversity.
- **Physical conditions** - e.g., size and shape of watersheds, amount of watershed above or below future snowline.
- **Ecological conditions** - e.g., divergence from healthy condition, presence of invasive species, amount of vegetation cover.
- **Hydrological conditions** - e.g., presence of wetlands, level of floodplain connectivity, soil water holding capacity, % of streams that are perennial, intermittent, ephemeral, whether the watershed is glacier-, snow-, or rain-fed.

Factors that could lead to relatively higher or lower **ADAPTIVE CAPACITY** of watersheds or WHMAs to climate change included:

- **Ecological conditions** - e.g., presence or absence of beaver activity, presence of invasive species, genetic diversity, presence of refugia.
- **Physical conditions** - e.g., topographic and geological diversity, presence of microclimates, stream basin connectivity (longitudinal, vertical, lateral, and temporal), presence or absence of barriers to movement.
- **Water management** - e.g., ability to manage water resources (via irrigation, reservoir operations), availability of water rights for instream use.
- **Land ownership** - e.g., private versus public lands and the ability to do larger scale restoration efforts.
- **Support and resources** - e.g., funding and public support.

All of some of the exposure, sensitivity and adaptive capacity factors identified by workshop participants could be used to assess the relative climate change vulnerability of key properties or watersheds across the state. Ultimately, this information on climate change vulnerability could be included in habitat project designs when framing project goals and desired outcomes.

Table 3. Potential measures of exposure, sensitivity and adaptive capacity for **<u>WATERSHEDS</u>** across Wyoming

EXPOSURE	**SENSITIVITY**	**ADAPTIVE CAPACITY**
Exposure = The amount of change in climate experienced by a place or species. Higher Exposure = More Vulnerable	**Sensitivity** = The extent to which a species or place is affected by changes in climate. Higher Sensitivity = More Vulnerable	**Adaptive Capacity** = The ability of the landscape (or species) to cope with or respond to changes in climate. Lower Adaptive Capacity = More Vulnerable
<u>Potential Measures of Exposure:</u> • **Changes in temperature and precipitation:** - Watersheds that already receive more precipitation from rain rather than snow might be less exposed - Basins with a high percentage of area above future snowline will be less exposed to climate change. - Watersheds that are projected to experience a greater amount of warming are likely to be more vulnerable. • **Changes in timing of water inputs:** - Natural streamflow might be higher in fall/ winter, lower in summer. Reaches receiving diverted water could be less vulnerable, pending changes in water use. • **Current water management:** - Areas where water management is already intense could have increased exposure of the area to water issues.	**<u>Potential Measures of Sensitivity:</u>** • **Distribution/abundance of sensitive species:** Watersheds that harbor sensitive species may be more sensitive/vulnerable: - Moose (b/c rely on riparian areas and are sensitive to warming) - Bluehead sucker (b/c they are currently constrained by barriers. - Migrating species with high fidelity to their routes (mule deer, cranes, etc.) - American Bittern (few options to move) - Foothill species (b/c they may be affected by lower elevation competitors/predators moving up, but they may not be able to migrate up into mountainous areas because physical conditions may not be suitable). - Areas with relatively more species - Areas with a high amount of the state's fish biodiversity will be relatively more vulnerable. - Fish species near the edge of their range may be pressured by temperature increases near their thermal tolerances. • **Physical conditions:** - Basins with lower elevation and smaller basins may be relatively more sensitive. - Long, narrow basins are more sensitive to flooding from high intensity rainfall events. - Basins with low percentage of watershed above current and future snowline are more sensitive to higher temperatures but less sensitive to reduced SWE (since they receive more inputs from rain than snow). • **Ecological/Hydrological conditions:** - Basins with fewer wetlands and lower soil water holding capacity are more sensitive to increased rainfall and droughts. - Basins with higher % of highly erodible soils and lower % of vegetative cover are more sensitive to high intensity rainfall. - Basins with fewer wetlands and less groundwater connection are more susceptible to extreme low flows due to reduced summer precipitation. - Amphibians may be more vulnerable to declines in areas with reduced floodplain connectivity and/or subsurface recharge. - Areas where water availability is relatively more secure and stable will be less sensitive/vulnerable.	**<u>Potential Measures of Adaptive Capacity:</u>** • **Ecological conditions:** - Watersheds that lack beaver or functioning riparian communities will have lower adaptive capacity and will lack water storage, aquifer recharge, temperature buffers and floodplain connectivity. - Amphibian habitat adaptive capacity may be reflected by historic trends in ephemeral aquatic habitats. - Current cheatgrass infestation in the area and surrounding areas = lower adaptive capacity, more vulnerable. • **Physical conditions:** - Streams/basins with more connectivity (longitudinal, vertical, lateral, and temporal) have greater adaptive capacity - Drainages with headwaters out of state or otherwise inaccessible=reduced ability to manage/meet interstate compact agreements - Local geology and its ties to the aquifer is a big driver in SE Wyoming - geological conditions could confer greater or lesser adaptive capacity. • **Water management:** - Areas with irrigation = higher adaptive capacity (b/c can manage water inputs to wetlands or other ecosystems). - Irrigation diversions reduce adaptive capacity. - Improved water irrigation practices could reduce return flows, resulting in less water in the creeks. - Proportion of flood versus pivot irrigation - Higher availability of water rights across sub basins = greater adaptive capacity - Areas with high urban water development via wells may have lower adaptive capacity. - Amount of multiple use across the area and potential limited management options. • **Human development:** - Level of human development - Lower development creates more opportunities for wildlife and ecosystems to adapt. • **Land ownership and management:** - Private versus public lands and the ability to do larger scale restoration efforts • **Support and resources:** - Public perception of management partners - Availability of funding

Table 4. Potential measures of exposure, sensitivity and adaptive capacity for WILDLIFE HABITAT MANAGEMENT AREAS (WHMAs) across Wyoming

EXPOSURE	SENSITIVITY	ADAPTIVE CAPACITY
Exposure = The amount of change in climate experienced by a place or species. Higher Exposure = More Vulnerable	**Sensitivity** = The extent to which a species or place is affected by changes in climate. Higher Sensitivity = More Vulnerable	**Adaptive Capacity** = The ability of the landscape (or species) to cope with or respond to changes in climate. Lower Adaptive Capacity = More Vulnerable
Potential Measures of Exposure: • **Physical conditions:** - General geology of area (e.g., that contribute to natural lakes (slope)) - Elevation of WHMA - Elevational gradient within the watershed - Aspect - Geo-hydrology and watershed area size for potential recharge - Soil texture - Is it a closed watershed or open? (ability to recharge; some only snowpack dependent) • **Future temperature/precipitation conditions:** - Magnitude of change in SWE - Magnitude of change in precipitation - Frequency of drought - Proportion of precipitation falling as rain versus snow • **Changes in disturbances:** - Expected changes in disturbances such as bark beetle outbreaks, wildfire - Increased frequency of high-concentration sedimentation events in the rivers and at confluence areas of the reservoir - Longer growing seasons, more fuel for wildfires/ increased fire intervals • **Ecological/Hydrological Conditions:** - Places with more open water may experience greater exposure to changes in river ice formation - Reservoir shoreline areas and backwater zones in rivers may be exposed to increased variability in wetting-drying along from lake level fluctuations.	**Potential Measures of Sensitivity:** • **Distribution/Abundance of Sensitive Species:** - Occurrence/abundance of generalist vs. specialist species - Number or conservation rank of species experiencing conditions exceeding physiological limits - Public sensitivity about numbers of species managed in the area (economic importance) • **Ecological Conditions:** - NDVI change (i.e., drought resilience of plant communities) - Vegetation communities - current place in state and transition models (Prioritize work based on how much effort would be necessary to maintain or reverse a community) - Presence/abundance of invasive species and non-natives - Divergence from proper functioning vegetative community - Native riparian vegetation species are more sensitive to big/sudden fluctuations in water levels relative to generalist/invasive species. - Presence or susceptibility to invasive annual grasses that will change susceptibility to fire • **Hydrological Conditions:** - % of streams that are perennial, intermittent, ephemeral - Hydroperiod for wetlands (% makeup) - Water source (e.g., glacier melt, snow melt, rain-fed) - Water budget - the amount of water held on the landscape - Degree of stream incision/ connectivity to floodplain	**Potential Measures of Adaptive Capacity:** • **Ecological Conditions:** - %, density, diversity of noxious weeds present - Canopy density/cover (& how that might influence infiltration) - Age class diversity - Presence of variable sites/niches for refuge from extreme events. - Genetic diversity / isolated populations • **Physical conditions:** - WHMAs with greater topographic variability can provide more microclimates - Presence of water features (rivers/wetlands) - Conservation potential for beaver & dam building limitations - Barriers to movement to reach suitable niches during extreme events - % of stream connectivity • **Water management:** - % total water tied up in water rights - WHMA's with more and senior water rights held by WGFC have greater adaptive capacity - Reservoir operations could be used to increase adaptive capacity by helping add water during droughts, and keeping water cooler during hot periods • **Land ownership and management:** - Land ownership (fragmentation) - WHMAs with high road densities have lower adaptive capacity (are more vulnerable) because there are barriers to species' ability to track optimal conditions as climate changes - Mineral rights ownership/exploitability of sub-surface minerals - WHMAs with, or adjacent to, irrigation districts and agricultural activities will likely be less able to adapt given the increase in mono-culture habitats

What's Different About "Climate-Informed" Management Strategies and Actions?

Building off of discussions about climate change impacts and vulnerabilities, workshop participants tackled the question: ***"What, if anything, might we need to do differently about our work to be effective in light of expected climate changes and impacts?"***

To support this discussion, participants were introduced to two core concepts related to planning climate-informed management goals and actions. First, Dr. Frank Rahel presented the Resist-Accept-Direct (RAD) framework (Thompson et al. 2020) for determining management goals in the context of a changing climate. The RAD Framework encourages managers to be intentional about how their goals relate to changes brought about by climate change. **Resisting** change involves taking actions to try and maintain ecosystems at a historical baseline. **Accepting** change acknowledges that some changes cannot be fully resisted and may even be acceptable to stakeholders; therefore, managers can accept or allow those changes to happen. **Directing** change is a more proactive approach to shaping ecosystem changes towards a new state, and may be appropriate or even necessary when changes are so dramatic that resisting is untenable and there is a feasible opportunity to steward changes towards a more desirable outcome.

Next, Dr. Molly Cross shared examples of how conservation practitioners are already starting to modify their conservation approaches to be more successful in a changing climate, by altering the design of their actions (WHAT), the locations where they are working (WHERE), the timing and urgency of their approaches (WHEN), and the goals for which they are striving (WHY). These "4 W's" offer useful prompts for a discussion about what, if anything, might need to be different about the agency's conservation and management work. Although not all conservation projects need to be modified in the What, Where, When and Why in order to be effective in a changing climate, it is important to take time to pause and ask these questions to ensure that the agency's work is as effective as possible.

Participants were divided into four breakout groups, each of which focused on one of the following management strategies that are common to WGFD's work:

- Riparian habitat protection and restoration
- Stream restoration
- Fish passage and stream connectivity
- Water management

Each breakout group discussed whether and how their assigned strategy -- and the actions undertaken to achieve that strategy -- might need to be modified in terms of the What, Where, When, and Why, in order to be effective in a changing climate (See Appendix C for completed worksheets from breakout discussions). Below, we summarize aspects of WGFD's habitat protection and enhancement work that might need to be modified to increase its effectiveness, and examples of strategies that may not necessarily need to be different, but which were flagged as being particularly important or urgent to address climate change impacts.

Climate-Informed Modifications to Current Practices:

- **Design projects under the assumption of increasing likelihood of higher high flows, lower low flows, and more frequent extreme flood events, rather than historic or current hydrological conditions.**

  As flows become more variable, it may not be adequate to use historic or current hydrological conditions as a benchmark for designing or retrofitting water-related infrastructure such as culverts, road crossings, irrigation diversions, and fish screens. These structures will be more effective if they proactively take into account future hydrological dynamics. The potential for more frequent, larger floods also could be incorporated into stream restoration designs, such as using larger woody materials that can withstand higher stream power. Increased flow variability, including more frequent extremely low flows, could be addressed using multi-level stream beds that provide a core channel that will have water even during very dry conditions.

- **Use plant species or genetic stock that is more likely to thrive under future climate conditions in restoration projects.**

  Changing climate conditions may make some areas no longer suitable for plant species that have thrived there in the past. Shifting the selection of plant species or genetic stocks towards those that are expected to be well-suited to future climate conditions is one strategy that could be used to improve the effectiveness of planting projects in riparian or wetland ecosystems. For example, managers could shift to sourcing willows for bank stabilization projects from warmer locations, or planting drought-tolerant native species when restoring riparian habitats.

- **Craft restoration and connectivity projects with future species' ranges and habitat conditions in mind.**

  As climate change causes some currently occupied areas to become unsuitable and improves the suitability of habitats in other areas, plants and animals will need to be able to move and shift their ranges in response. Habitat protection and enhancement efforts will therefore be more effective if they are designed to provide access to a variety of habitats that are likely to remain or become suitable in the future.

For example, this could include evaluating the effects of climate change on planned native fish restoration projects to identify stream reaches that may become available to those fish in the future (but which are not suitable today), and reaches where projects could fail due to changes that cannot be prevented. This information could also influence fish passage work, to focus on removing barriers in places where vulnerable fish populations will need to move in response to climate change, and installing barriers in places where climate change might facilitate the expansion of non-native aquatic species. Another example includes prioritizing riparian restoration projects in areas that are likely to retain perennial flows under future climate scenarios to ensure long-term vegetation growth.

Projects focused on amphibian habitat could be designed and planned with an eye toward climate change induced long-term and seasonal water shortages. These enhancements could address expected drought and evapotranspiration rates by creating deeper pools, for example, to maintain water through the breeding season. Wetland networks could also be emphasized to ensure connectivity as existing wetlands become increasingly dry.

- **Take climate change into account when prioritizing projects and articulating project goals.**

  Many factors go into decisions about which projects to prioritize to receive funding, capacity, and other resources. Climate change can be one of those considerations. For example, the agency could consider prioritizing areas for projects that are more likely to be resilient to climate changes and provide climate adaptation benefits to numerous species. Or the priority might be placed on river, riparian and wetland habitats where climate impacts are most immediate, or that house species of concern that are vulnerable to a changing climate.

  It may also be necessary to assess the feasibility of current project goals in light of climate change, and determine when to adopt goals related to Resisting, Accepting, or Directing climate-related changes. Although it may be possible to resist some climate changes and impacts in some places and times, it is likely that habitat management will also need to consider when and where to accept or even direct some climate-driven changes. For example, with the management of invasive species, it may be helpful to prioritize treatment areas based on whether climate models predict that those invasive species will increase or decrease in a changing climate. Invasive species control efforts could then be targeted at areas where there is a higher potential for success.

- **Increase flexibility around water management and habitat restoration to address new problems that will need new solutions.**

  As the climate changes, new and unanticipated problems and opportunities for fish and wildlife habitat management may unfold. Agencies such as WGFD would therefore benefit from increased flexibility to deal with those emerging challenges and opportunities. For example, legislative and policy issues around water management could be modified to provide more flexibility in how water resources are managed for the benefit of fish, wildlife and habitats as climate change alters water availability and timing. Increasing staff expertise and attention to water legislation and policy will allow the Department to be proactive.

Strategies and Actions With Increased Priority and/or Urgency:

- **Increased importance of retaining and conserving water.**

  Climate change is expected to have significant impacts on hydrology across the state, including increasing drought frequency, changing seasonal water availability in snowpack driven systems, increasing temperatures and evapotranspiration, and increased competition from other water users due to reduced supply. These changes add urgency and priority to strategies that the agency is already engaged in to increase natural water storage and improve the efficiency of water use for habitat enhancement and protection projects. This includes expanding water retention through natural and man-made practices that serve to raise the water table, encourage floodplain connectivity, and recharge shallow aquifers, such as translocating beaver or constructing beaver dam analogs, retention ponds, and other process-based restoration approaches. To address climate change concerns, these actions will need to be implemented at a larger scale and in new locations within watersheds, including upland meadows and within water irrigation systems to catch and save runoff. It could also include locating wetlands and flood irrigation in recharge areas (to increase aquifer recharge), and increasing irrigation-related water savings via more efficient techniques.

- **Increased importance of securing and managing water rights.**

  The WGF Commission holds 1076 water rights on its various properties for maintaining and enhancing fishery and wildlife populations. These include irrigation rights for producing wildlife forage; diversionary and storage rights to sustain wetlands and ponds; storage rights in reservoirs to sustain sport fisheries; and negotiated agreements to protect water storage and provide environmental flow releases. In addition, WGFD identifies important fisheries for instream flow water rights and identifies flow levels needed to maintain or improve those fisheries. Currently there are over 250 stream miles protected with instream flow water rights. With increased pressure on changing water supplies, it will become increasingly important to maintain the validity of existing water rights by surveillance of competing users and asserting WGFD rights through proper State Engineer's Office procedures. It will likewise be increasingly important to pursue additional water rights to protect and sustain fishery and wildlife resources. Climate-driven changes in agricultural intensity may create new opportunities for the state to secure additional water rights, which could be used to augment flows during dry periods or in areas where water availability decreases. The purchase of additional water rights could give the WGFD more certainty and control, and create opportunities for using water rights in new and creative ways to support wildlife conservation as the climate changes.

- **Increased importance of riparian restoration and protection.**

  Improving riparian habitat for wildlife connectivity via management of grazing, fencing, and riparian restoration is already a high priority for WGFD, but it becomes increasingly important as species need even greater opportunities for movement to track changing climate conditions. For example, ungulates may display greater riparian zone dependency if upland habitats dry out and become less desirable. Aquatic and terrestrial species may also need to move further upstream and upslope to track changing climate and habitat conditions.

- **Greater urgency for landscape-scale conservation and management.**

  Although not new to habitat management, thinking about and investing in conservation at a landscape scale is critical to addressing climate change impacts and helping species adapt. For example, keeping floodplains connected and functioning properly, especially with respect to aquifer recharge and sustaining later season return flows will be essential to addressing hydrological changes at a watershed scale. A focus on increasing connectivity at a larger watershed scale could create opportunities for large-scale climate-driven movements as habitat suitability changes. Maintaining or enhancing networks of wetlands will be important to providing connectivity for and maintaining populations of wetland-dependent species and hedge against local drying across seasons and years.

Priority Climate-Informed Actions for the Statewide Habitat Plan

Workshop participants were asked to identify climate-informed actions that could be included in the 2020 SHP revision, for each of the four focal geographies. Across all four breakout groups, over 75 habitat management actions were identified to help address climate change impacts on river, riparian, and wetland habitats in Wyoming. These actions ranged from managing land and water use with an eye towards future conditions; building watershed health and resilience to a changing climate; maintaining species diversity and habitat needs in a changing climate; making climate-informed decisions about angling, trapping, and setting goals for habitat management areas; prioritizing habitat management efforts using a climate change lens; and establishing and implementing monitoring methods and protocols that can help to anticipate changes and set climate-informed priorities (Table 5).

There was a great deal of emphasis on actions relating to water availability and use. Nearly 20% of the identified actions related to water rights, water storage, water management, and irrigation.

Table 5. Climate-informed actions to consider for the 2020 WGFD Statewide Habitat Plan.

Category	Sub-category	Example Actions
Land & Water Use	**Grazing**	Work with permittees and agencies on grazing management to build the resilience of vegetation.
		Develop grazing plans that can adapt to potential climate impacts.
		Explore vegetation management actions aimed at benefiting terrestrial species in a changing climate (with residual effects on aquatic species).
		Explore strategies (e.g., riparian fencing) to exclude trespass cattle from riparian areas to maximize riparian function and resilience.
		Develop strategies to market conservation practices to landowners - Potentially use wildlife species (turkey, whitetail deer, pheasant) instead of native non-game fish, to sell work.
		Monitor changes in vegetation species composition on winter ranges to ensure forage availability for wintering wildlife.
	Habitat Easements and Water Rights	Purchase unused or additional water rights.
		Long term "habitat easements" for riparian corridors, similar to a conservation easement, but just for a specific habitat that would protect and enhance a riparian area for long term. Farm Service Agency has the CCRP (Continuous Conservation Reserve Program) program that is similar, but the longest an easement can last is 15 years. Ideally, we would like to extend the length of this program.
		Incentivize habitat improvements with private landowners.
		Find private landowner champions to highlight projects.
		Lean on partners (Conservation Districts, USFWS, NRCS) to take an active role in habitat improvements.
		Sell unused water rights.
		Changing agricultural intensity may allow the state to buy more water rights, which could be used to augment flows during critical periods. By buying water rights we have more certainty and control. How can we use our water rights in new and creative ways to support wildlife conservation?
	Irrigation	Private landowner incentive programs for dry-land agriculture to reduce water use.
		USDA programs for stream course buffers in cropland areas (with WGFD Trust fund or other to cost share on practices).
		Assess irrigation technology (flood/pivot/sprinkler) for best use given climate change ramifications.
		Consider that flood irrigation can contribute to higher stream temperatures from return flows. Could switch to pivot irrigation lower in the watershed and store more water (by beaver, etc.) higher in the watershed to keep water temperature lower throughout the stream. Manage return water in efforts to reduce temperature increases and maximize total system function, i.e return to river/riparian/wetland as soon as applicable.
		If applicable, switching from flood irrigation to pivot or other more water-efficient methods (although see other points about need to better understand full water cycle implications of different irrigation technologies).
		WGFD system capacity is currently less than our water rights. Look forward to potential flow regime changes to ensure that our infrastructure can capture water rights.
	Partnerships	Partner with and support groups that encourage smart growth and the retention of agricultural open lands, and control the growth of subdivisions.
		Be aware of and use agency programs (NRCS/ Farm Bill) to incentivize and facilitate water and wetland and riparian improvements.
		Enhance capacity to track water management opportunities and engage with State Agencies and legislature to promote Department water use and rights.
	Water Management Plan	Work on water management plan to determine if WGFD can use Bump Sullivan water shares for instream flows, wetland maintenance, fish production, pheasant production, etc. Assess water use requirements / needs of landscape or drainage (crop, range, instream flow needs, wetlands, stock reservoirs, irrigation storage reservoirs). Identify senior water rights users & subdivisions & impacts for water management regimes.

Watershed Health & Resilience	**Water-Holding Capacity/Flood & Drought Resilience**	Develop wet meadows and beaver complexes to increase water holding capacity on the landscape (and hopefully increase water delivery).
		Riparian vegetation management actions aimed at benefiting terrestrial species (with residual effects on aquatic species).
		Keep water in headwaters longer using natural approaches like beaver, BDA's, small rock dams, and other Zeedyk structures.
		Riparian Restoration - maintain high water table and cottonwood gallery through beavers, beaver dam analogs, and wetlands.
		Create staged channels to better accommodate higher high flows and lower low flows.
	Floodplain Connectivity	Enhance and maintain floodplain connectivity on Shoshone and Big Horn Rivers - e.g., ice jams have removed dikes allowing oxbow connectivity.
		Emphasize floodplain reconnection with stream restoration to reduce future impacts of flooding.
		Improve stream channel function where necessary to increase floodplain connectivity.
	Sedimentation & Erosion	Protection and improvement of irrigation diversion and infrastructure.
		Yellowtail WHM- specific: Evaluate if upgrades to irrigation equipment/practices are required to reduce flooding, sedimentation.
		Consider diversion designs and management that would limit sediment from entering the systems due to changing flood regime.
		Remove unnecessary/unused 2-tracks.
		Implement overland erosion control measures.
		Beaver dam analog and willow-planting in erosion-prone areas; upland planting to hold soil together.
		Explore expanded use of drought-tolerant native plants.
		Identify management options/projects that would positively impact downstream systems (e.g., aspen restoration).
	Water Temperature	Enhance spring creeks as potential cool water refugia and reconnect these systems.
		Plant woody species for stream shading.
		Manage return water in efforts to reduce temperature increases and maximize total system function, i.e., return to river/riparian/wetland as soon as applicable (also noted above under irrigation strategies).
Maintain Species Diversity	**Genetic Assessment**	Range-wide genetic assessment of Yellowstone cutthroat trout to determine genetic variation/uniqueness of East Fork population.
		Research feasibility of genetic manipulation to help fish species adapt to predicted climate conditions, such as warming water.
	Manage Invasive Species	Inventory of invasive plant and animal species, and development of treatment plans. Consider downstream/upstream management for success in both aquatic and terrestrial invasion control.
		Rapid response to new invasive species.
	Assess Species-Specific Climate Vulnerability and Refugia	Species-specific climate-vulnerability assessments.
		Exploration of climate refugia, even outside of historic ranges (i.e., for imperiled species) that may serve as key source populations and allow for other limitations to be addressed.
	Manage Movement	Barriers - Construct barriers now that will prevent upstream movement of undesirable non-native species. Barrier(s) can prevent future interactions with species of conservation need (SGCN) that may be able to persist further upstream following climate change.
		Improve fish passage for SGCN by removing barriers and/or constructing fish ways at strategic locations that will allow movement currently and in the future to areas that may have suitable conditions (temperature and streamflow) following climate change.
		Connectivity-focused stream restoration for Great Basin fishes.
		Translocation - Future translocations of desired fishes to areas with suitable conditions.
		Active transition of community composition/sportfish to better adapted and preferred species.
		Identify strains of fish permitted to be stocked that are possibly more adapted to warming water temperatures

Game & Fish Management	**Angling**	Angling closures related to water temp and flow conditions.
	Trapping	Close areas to beaver trapping/change trapping regulations. Enact monitoring.
	WHMA management objectives	Conduct an exercise to see if management objectives of WHMAs would change based on climate projections.
Prioritizing Work/ Priority Designations	**Large-Scale Projects**	Emphasize watershed-scale work - prioritize more extensive work in fewer drainages.
	Climate Vulnerability, Resilience, and Risks	Develop an approach to identify vulnerabilities of landscapes, riverscapes, and species -- use to prioritize areas for protection & restoration.
		Develop a database of species-specific tolerances (aka climate vulnerability).
		Inventory of water temperatures by watershed and prioritize management based on species-specific tolerances.
		Identify places with higher risk of future flooding to prioritize floodplain reconnection with stream restoration to reduce impacts.
		Conduct widespread habitat assessments to determine riparian resiliency and appropriate diversity of habitats within the system (incorporate climate vulnerability into habitat assessments which are already conducted).
	Triage	Consider sacrifice areas where current conditions are very poor (e.g., Bear River wetlands near Cokeville).
	Stream Connectivity	Select sites that may be appropriate for construction of barriers now, that will prevent upstream movement of non-native species that are undesirable. This barrier(s) can prevent future interactions with SGCN that may be able to persist further upstream following climate change.
		Use predicted future instream habitat conditions to prioritize fish passage projects.
	Partnerships	Use remote sensing to prioritize areas and landowners to work with (& monitor changes).
	Beaver-Related Projects	Explore tributary drainages for suitable habitat to reintroduce beaver. Emphasis on identifying locations; include all headwaters.
		When transplanting beaver to areas for increased water storage, aquifer recharge and floodplain connectivity, consider the watershed's vulnerability to climate change.
		Facilitate the development of a working Beaver Restoration Assessment Tool (BRAT) model based on useful Landfire and NHD Plus data.
	Water Management	Use flow, temperature, and wetland resiliencies and importance to multiple species groups to help prioritize stream segments for instream flow water rights studies.
		Given predictions related to water shortages/drought, use monitoring data to identify need for and prioritize water management actions.
	Riparian and Stream Restoration	Use predicted future water temperature to identify stream courses and prioritize where to plant woody species for stream shading. Will also contribute to bank stability and prevent further downcutting.
Methods and Protocols	**Baseline conditions**	Find reference reaches (both terrestrial and riparian) to base future habitat improvements on.
	Aquatic monitoring	Streamflow & wetlands monitoring. Continue, increase. Include monitoring of inflows, evapotranspiration, water extents, etc. Use of remote sensing, in-situ equipment. Collect data to build on past flow monitoring to track significant changes in timing/amount/use. Determine, recommend minimum. Help understand local processes in light of predictions.
	Vegetation monitoring	Monitor changes in vegetation species composition on winter ranges to ensure forage availability for wintering wildlife.
	Large-scale monitoring	Develop novel ways of conducting large scale monitoring efforts efficiently (remote sensing, drones, loggers). Consider less monitoring in some cases.
	Design and Construction	New parameters for design criteria (e.g., design fish passage/culverts, irrigation infrastructure, stream restoration, etc. for floods that will be larger than typical).

Information and Research Gaps

The final session of the workshop was dedicated to gathering participants' input on: ***What does the Agency need to know in order to make better climate-informed decisions in the next 5 years?*** In response, participants identified a large number of research questions, data products, and inventories that could help support climate-informed management decisions for river, riparian and wetland habitats. Workshop organizers combined similar topics from this discussion into a refined list of 44 information needs related to several themes, including: riparian and wetland ecosystems; aquatic habitat and fisheries; beaver and other process-based restoration approaches; assessments of climate change vulnerability, refugia, and prioritization/planning; invasive species; fish passage and stream connectivity; hydrology and water balance; stream restoration; water management; and baseline data and monitoring (Appendix D).

After the workshop, we solicited input on which of the identified information needs are considered most useful by WGFD staff. We gathered this input via an online survey that was sent to all WGFD staff. The survey asked respondents to indicate how useful each of the 44 identified information needs would be to their ability to consider climate change effects on their work on river, riparian, and wetland habitats (using a scale of "Not At All Useful" to "Very Useful"). We also asked for additional details about those information needs that were flagged as "Very Useful", and an indication of how that information would be used in management decisions. Overall, 28 WGFD staff completed the information needs survey, representing a range of disciplines and departments within the agency (Figure 2). Most of the survey responses came from workshop participants (57%), although some WGFD staff that did not attend the workshop also chose to complete the survey (43%).

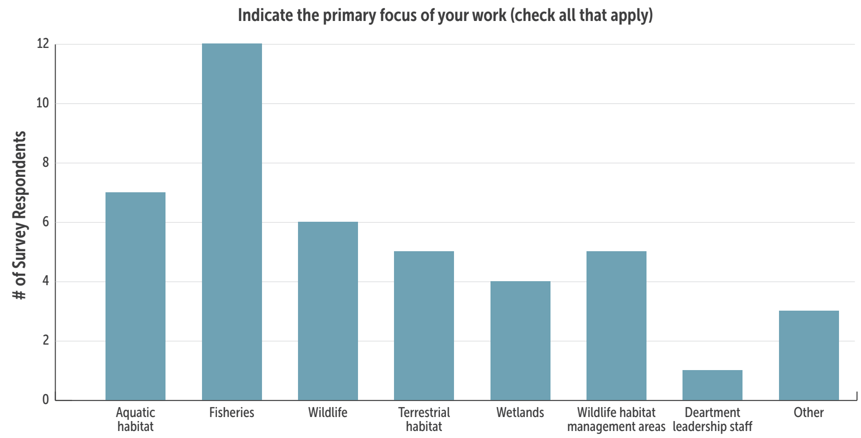

Figure 2. Primary focus of respondents to the Information Needs survey (total of 28 respondents).

Each of the 44 information needs had at least one survey respondent indicate that it would be "Very Useful" to their work; however, there were some information needs that were more consistently identified as being useful to WGFD staff (Figure 3). Eight (8) information needs were especially highly rated as being useful to climate-informed habitat management efforts, with over 60% of survey respondents indicating that they were "Useful" or "Very Useful" (Table 6, Tier I information needs). These include efforts to identify important places for habitat management actions, such as streams that may become more (or less) suitable for particular fish species under a changing climate, or areas of "climate refugia" for imperiled species. They also include research designed to support our understanding of the effects of particular climate-informed management actions, such as the influence of process-based restoration approaches on water availability for downstream users, or how upland habitat treatments affect watershed hydrology under more intense precipitation events, or what are the tradeoffs and benefits of different water management approaches (e.g., flood vs. pivot irrigation, or managing water for instream vs. out-of-stream habitats) in a changing climate. Lastly, they include information needs related to invasive species, such as which invasive species might be expected to increase or arrive in Wyoming as the climate changes, and what are the best management strategies for disadvantaging invasive plant and fish species.

An additional twelve (12) information needs were considered to be "Useful" or "Very Useful" to between 50-60% of survey respondents (see Table 6, Tier II information needs). All of the information needs identified during the April 2020 workshop are included in Figure 3 and spelled out in greater detail in Appendix D. Appendix D also includes survey responses on how respondents anticipate using the information in their work, and five additional information needs that were not discussed at the workshop, but which were identified by respondents as being "Very Useful" to their work.

One overarching recommendation provided by a survey respondent was that WGFD should consider building the human capacity needed to coordinate climate-related research, analysis, and data management. Even if research is conducted in partnership with other entities, WGFD would likely benefit from a coordinator with quantitative expertise to be able to see the big picture, direct all these efforts into usable information, and manage climate-related datasets..

All of these results on information needs will be shared with climate researchers in the region, including those affiliated with the North Central Climate Adaptation Science Center (NC-CASC). One of the goals of the NC-CASC is to foster applied climate research in support of natural resource management and decision-making. The decision-relevant information needs identified through this workshop will therefore be useful inputs to the NC-CASC's evolving Strategic Science Plan.

Figure 3. Usefulness of each information need identified at the 2020 WGFD Climate Change Workshop. Most information needs received a total of 28 responses, except for information needs #9-14, #22, #28-31, which each received 27 responses. More detailed descriptions of the information needs and ranking results can be found in Appendix D. A double asterix (**) indicates information needs that were deemed "Useful" or "Very Useful" by ≥60% of respondents; a single asterix (*) indicates information needs that were deemed "Useful" or "Very Useful" by 50-60% of respondents.

Table 6. Information needs perceived as most useful to considering climate change effects on Wyoming Game and Fish Department work on river, riparian, and wetland habitats

Tier I: Information Needs with ≥60% "Useful" or "Very Useful" Responses	Tier II: Information Needs with 50-60% "Useful" or "Very Useful" Responses
Beaver and other process-based restoration approaches: • Determine how process-based restoration approaches (e.g., beaver dam analogs, beaver, Zeedyk structures, etc.) affect the timing and quantity of water delivered to downstream water rights holders. **Aquatic habitat and fisheries:** • Develop fish habitat models that incorporate climate variables into stream suitability/vulnerability analyses for species and assemblages; Identify streams that could become suitable under future climate scenarios. **Climate refugia, prioritization, and planning:** • Identify climate refugia (within and outside of historic range) for imperiled species that may serve as key source populations and allow habitat limitations to be addressed. **Invasive species:** • Determine which invasive species we might expect to see that are not yet in Wyoming. • Identify management or habitat actions that disadvantage invasive fish and plant species. **Hydrology and water balance:** • Understand how upland habitat treatments (juniper removal, sagebrush mowing, etc.) link to water release into the watershed and system impacts with more intense precipitation events. **Water management:** • Develop a better understanding and examples of tradeoffs for water use and wildlife benefits for flood versus pivot irrigation. • Analyze tradeoffs between managing water use for instream vs. out-of-stream habitats (e.g., wetlands) (i.e., determine habitat and ecosystem function gains and losses per cfs).	**Riparian & wetland ecosystems:** • Investigate how different amounts of change in climate would lead to changes in a resource of interest (e.g., wetland area fluctuations in response to changes in precipitation). **Beaver and other process-based restoration approaches:** • Determine how process-based restoration approaches (e.g., beaver dam analogs, beavereedyk structures, etc.) affect shallow alluvial aquifers and riparian areas. • Assess beaver translocation success or failure to determine what drives survival and establishment of colonies, and understand spatial variability. **Aquatic habitat & fisheries:** • Develop an inventory of water temperatures by watershed and prioritize management based on species-specific tolerances. **Climate refugia, prioritization, and planning:** • Identify potential translocation sites for species of conservation concern that consider future climate conditions not just current climate conditions. • Develop a standardized, systematic protocol for evaluating and prioritizing watersheds for protection and restoration as related to climate change, that considers both aquatic and terrestrial needs. • Analyze management objectives of Wildlife Habitat Management Areas (WHMAs) relative to climate change predictions. **Climate change vulnerability assessments:** • Develop a database of species-specific tolerances of changes in climate. **Invasive species:** • Analyze the existing and potential future location of barriers in key watersheds relative to keeping native and non-native fish species apart. **Fish passage and stream connectivity:** • Develop or adjust design criteria for fish passage structures and culverts to account for larger floods and lower base flows. **Stream restoration:** • Identify places with higher future risk of flooding to prioritize floodplain reconnection with stream restoration to reduce impacts. • Predict future bankfull discharge and sediment transport resulting from increased peak flows and precipitation intensity, for use in stream restoration design.

Post-Workshop Evaluation

We asked participants to complete a post-workshop evaluation survey indicating how the workshop affected their knowledge, familiarity, and comfort with considering climate change impacts in their work. The survey illustrated several ways that the workshop was successful in advancing WGFD staff's ability to consider climate change in their work. Of the 35 WGFD staff that completed the survey, over 85% indicated that as a result of the workshop they:

- Gained new knowledge about climate change projections and impacts.
- Felt more comfortable integrating climate change information into their work.
- Felt more familiar with approaches and tools for climate-informed conservation planning, and climate change adaptation strategies and actions relevant to their work.
- Learned about new materials, tools, and resources that they can use to improve their understanding of climate change and impacts.

Approximately half of respondents said that they "met" new individuals with whom they will likely develop or share information about climate science in the future.

Nest Steps

The April 2020 Climate Change Workshop represented a valuable step in advancing WGFD staff's consideration of climate change in their habitat management work. Next steps to apply and build on the discussions at the workshop include:

- Incorporate climate-informed habitat management strategies into the 2020 Statewide Habitat Plan revision.
- Share this report within WGFD via a dedicated webpage, and formal and informal presentations.
- Present a summary of workshop discussions and products to the Wyoming Game and Fish Commission.
- Consider organizing similar climate change discussions within WGFD focused on additional regions, ecosystem types, or WGFD programs (if appropriate, using worksheets from this workshop to guide discussions - see Appendix C).
- Share the identified information needs with climate researchers in the region, and explore targeted research partnerships to address some of the high priority information needs identified by WGFD staff.
- Share methods and results from this project with other natural resource managers interested in making climate-informed management decisions.

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Appendix A - Workshop Agenda & Participant List

AGENDA

Wyoming Game and Fish Department workshop on
Climate Change and the Statewide Habitat Plan
April 28-30, 2020
Virtual Workshop

Workshop Goals:
- Learn about the best-available climate change projections and research on impacts to river/riparian/wetland habitats.
- Discuss the consequences of climate change for Statewide Habitat Plan (SHP) priorities – including the identification of priority areas for protection and restoration, and recommended actions within those areas.
- Identify specific climate-informed habitat protection and restoration actions that could be taken on WY Wildlife Habitat Management Areas or in specific watersheds.
- Develop a list of data/information/analyses would be useful for making climate-informed decisions in the near- and longer-term (i.e., what is not currently available but could be the focus of future research).

Desired Outputs:
- Report that summarizes: 1) how climate change could influence the selection of priority habitat protection/restoration areas in the SHP and the design of conservation actions within those areas, and 2) high priority climate research/data/information needs relevant to the SHP in the near- and long-term.
- List of climate-informed habitat protection and restoration actions that could be taken on WY WHMAs or in specific watersheds.

DAY 1 – TUESDAY APRIL 28 - 1:00-4:30pm

Climate Science Webinar (Open to all WGFD)

1:00-1:05pm - Welcome and overview of webinar
1:05-1:30pm - Recent trends in climate across Wyoming (Bryan Shuman - University Wyoming)
1:30-1:55pm - Future climate projections (Imtiaz Rangwala - University Colorado-Boulder)
1:55-2:15pm - Impacts on snow and streamflow (Ben Livneh - University Colorado-Boulder)
2:15-2:35pm - Impacts to fisheries (Annika Walters - University Wyoming Coop Unit)
2:35-3:00pm - Introduction to climate-informed conservation planning and examples of climate adaptation in action (Molly Cross - Wildlife Conservation Society)
3:00-3:15pm - Impacts to wetlands (Patrick Donnelly - Intermountain West Joint Venture)

3:15-3:30pm - BREAK - TRANSITION TO WORKSHOP

Climate Workshop (By invitation)

3:30-4:30pm - Workshop Kick-off Session:
- Welcome, Introductions, Zoom meeting logistics
- Extended Q&A for Climate Speakers

DAY 2 – WEDNESDAY APRIL 29

10:00am-12:00pm
- Brief presentation on climate change vulnerability and introduction to Day 2 discussions
- Breakout group discussions - Climate change impacts of greatest concern within specific watersheds and/or Wildlife Habitat Management Areas (WHMAs)
- Plenary Discussion - How might impacts of greatest concern affect our ability to achieve the goals of the Statewide Habitat Plan.

12:00-1:00pm LUNCH BREAK

1:00pm-3:30pm
- Plenary discussion on assessing the relative climate vulnerability of Wyoming's watersheds and WHMAs.
- Breakout group discussions - What are the characteristics of watersheds/WHMAs that are relatively more vulnerable to climate change impacts?
- Report back from small group discussions.
- Plenary discussion: How does relative climate change vulnerability of watershed/WHMAs relate to goals that are possible in those areas (e.g., related to managing for persistence of habitats that are there now vs. building the resilience of habitats and species to changing conditions vs. enabling the transformation of ecosystems to new states).

DAY 3 – THURSDAY APRIL 30

10:00am-12:00pm
- Brief presentation on climate change adaptation strategies and introduction to Day 3 discussions
- Breakout group discussions: Identifying climate-informed habitat management strategies:
    - What current actions may need to be modified in order to be effective given climate change projections?
    - What current actions may no longer be recommended given climate change projections?
    - What new actions might be needed to achieve goals in a changing climate?
- Report back from Breakouts and Plenary Discussion about needs for altered management in the face of climate change.

12:00-1:00pm LUNCH BREAK

1:00pm-3:30pm
- Breakout group discussions - Identify specific strategies for focal watersheds/WHMAs
- Report back and Plenary discussion on:
    - What are some high priority strategies that WGFD managers can begin implementing?
    - What strategies should the SHP revision writing team make sure are included in the draft revision?
- Plenary discussion on information needs: What does the Agency need to know in order to make better decisions in the next 5 years?
- Wrap up and next steps

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ACRONYMS			
HTAG - Habitat Technical Advisory Group			
AHAB - Aquatic Habitat Biologist			
H&A - Habitat and Access			
THAB- Terrestrial Habitat Biologist			
GIS - Geographic Information System			
WLCI - Wyoming Landscape Conservation Intitiative			
USGS - U.S. Geological Survey			

Appendix B - Blank Climate Change Planning Worksheets

WORKSHEET #1 *- Future Climate Projections and Ecological Effects*

Purpose of Exercise = Compile a list of ecological consequences of projected climate changes for the focal ecosystem(s), in your assigned geography.

Instructions:

1. Start with 5 minutes of silent, individual reading, thinking, and jotting down ideas on Ecological Consequences - you can make notes on your own scrap paper or enter ideas directly into the Ecological Consequences column below (mark with your initials to help with tracking comments and discussions);
2. Round-robin sharing (1-2 examples of Ecological Consequences per person until all have been covered);
3. Open discussion and additional brainstorming (share verbally and/or through additional written ideas in the table); *Feel free to add additional "climate/hydrological variable" rows.*
4. General notes from the discussion (anything that doesn't fit into the Worksheet) can be inserted below the table.
5. Prepare for report-back by selecting 3-5 climate change impacts of greatest concern.

Geography:___________________(fill in)___________________________

SOURCES: [insert relevant information about the projected climate change data]

Climate/ Hydrological Variable	**Future Projected Changes** *[for selected time periods]*				**Ecological Consequences to Focal Ecosystem(s)**
	Range across all models & emissions scenarios	Mean for Moderate Emissions Scenario (RCP 4.5)	Mean for High Emissions Scenario (RCP 8.5)	**Model Agreement**	
Mean Temperature	Annual and Seasonal				
Precipitation	Annual and Seasonal				
Growing season length					
April 1 Snow Water Equivalent (SWE)					
Evapotranspiration					
Soil Moisture					
Intensity of precipitation					
Flood / Drought					
Mountain Snowline					
Streamflows					
[add rows as needed]					

***WORKSHEET #2** - Potential Measures of Relative Climate Vulnerability (of Watersheds, Management Units, etc.)*

Purpose of Exercise = Brainstorm potential measures of exposure, sensitivity and adaptive capacity that could be used in a spatial analysis of climate vulnerability for the focal ecosystem(s) (e.g., across watersheds, management units, or another spatial unit).

Instructions:

1. Start with 5 minutes of silent, individual thinking and jotting down ideas on measures of climate vulnerability - you can enter ideas directly into the columns below (mark with your initials to help with tracking).
2. Round-robin sharing (1-2 thoughts ideas per person until all have been covered) - make sure all ideas get entered into the table below.
3. Open discussion and additional brainstorming (share verbally and/or through additional written ideas in the table).
4. General notes from the discussion that do not fit into the Worksheet table can be inserted below the table.
5. Prepare for report-back by selecting 2-3 measures of exposure, sensitivity, adaptive capacity to share with the larger group.

EXPOSURE	SENSITIVITY	ADAPTIVE CAPACITY
Exposure = The amount of change in climate experienced by a species, ecosystem, or landscape. Higher Exposure = More Vulnerable *E.g., consider - Magnitude of change? Rate of change? In what climate variables or climate-related impacts?*	**Sensitivity** = The extent to which a species, ecosystem, or landscape is affected by changes in climate. Higher Sensitivity = More Vulnerable *E.g., consider - Is the ecosystem/species at the edge vs. center of its range? Have a narrow niche or low tolerance for different climate conditions? High vs. low tolerance for disturbances? Does the place harbor a lot of sensitive species?*	**Adaptive Capacity** = The ability of a species, ecosystem, or landscape to cope with or respond to changes in climate. Lower Adaptive Capacity = More Vulnerable *E.g., consider - Current conditions (healthy vs. degraded)? Size of protected area? Level of human use/impact? Intrinsic ability of species to adapt to changing conditions?*
Potential Measures of Exposure: ● *Example: Watersheds that are projected to experience higher magnitudes of drying are more vulnerable.* ● ● ● ●	Potential Measures of Sensitivity: ● *Example: Watersheds that harbor more climate-sensitive species (e.g., fish with low thermal tolerance), are more vulnerable to climate change.* ● ● ● ●	Potential Measures of Adaptive Capacity: ● *Example: Watersheds with high road densities have lower adaptive capacity (are more vulnerable) because there are barriers to species' ability to track optimal conditions as climate changes.* ● ● ●

WORKSHEET #3 *- What's Different? Climate-Informed Management Approaches*

Purpose of Exercise = Brainstorm ways that current management approaches might need to be modified to be effective in a changing climate, and new actions that might be needed to reduce climate change impacts and enable species and ecosystem adaptation.

Instructions:

1. Start with 5 minutes of silent, individual thinking and jotting down ideas on how current management approaches may need to be modified in the face of a changing climate - you can enter ideas directly into the WHAT, WHERE, WHEN and WHY columns below (mark with your initials to help with tracking).
2. Round-robin sharing (1-2 ideas per person until all have been covered) - make sure all ideas get entered into the table below. Add additional rows for other current management actions.
3. Open discussion and additional brainstorming (share verbally and/or through additional written ideas).
4. Brainstorm NEW actions that may be needed to achieve management goals (ADD NEW ROWS - still ask questions about What, Where, When and Why, to be as strategic as possible in the face of changing climate).
5. General notes from the discussion that do not fit into the Worksheet table can be inserted below the table.
6. Prepare for a report-back with the larger group by highlighting <u>2-3 examples of the need to do current work a bit differently</u>, and <u>2-3 NEW actions that might be needed</u>.

Management Strategy or Family of Actions:____________________(fill in)____________________________

Current Management Actions	**In what ways might goals and/or actions need to be modified to be more effective in a changing climate? (Or indicate whether and why current strategies do not need to be modified)**			
	WHAT *New actions or modifications to current actions*	***WHERE*** *Take actions in locations that are strategic*	***WHEN*** *Change in the level of urgency or timing of actions*	***WHY*** *New or modified objectives that are forward-looking*
EXAMPLE: Re-vegetation of riparian areas	• *Use riparian species that are well-suited for future climate conditions.*	• *Prioritize streams that are projected to retain perennial flows that can support riparian vegetation under future climate.*	• *Re-vegetation is urgently needed to stabilize stream banks <u>before</u> a big flood (which are becoming more likely).*	• *Riparian vegetation helps prevent erosion during floods, but also provides corridors for wildlife to move and track optimal climate conditions.*

WORKSHEET #4 *- Priority Climate-Informed Actions for Focal Watersheds/WHMAs*

Purpose of Exercise = Identify specific, climate-informed management actions for the focal ecosystem(s) and geography. ***To help your brainstorming, review the Climate Impacts Worksheet #1, and the What's Different Worksheet #3.***

Instructions:

1. Start with 5 minutes of silent, individual thinking and jotting down ideas on specific, climate-informed management actions for the focal ecosystem(s) and geography - you can enter ideas directly into the table below (mark with your initials to help with tracking).
2. Round-robin sharing (1-2 ideas per person until all have been covered) - make sure all ideas get entered into the table.
3. Open discussion and additional brainstorming (share verbally and/or through additional written ideas in the table).
4. General notes from the discussion that do not fit into the Worksheet table can be inserted below the table.
5. Prepare for report-back - 3-4 high priority actions.

Geography:____________________(fill in)____________________________

Priority Climate-Informed Management Actions	**Briefly - Is it a new action? If not, is there any difference from current practice (e.g., WHAT, WHERE, WHEN, WHY)?**	**Notes (e.g., applicability outside of the focal area you are discussing)**

Appendix C - Completed Worksheets

***Filled-in versions of WORKSHEET #1** - Future Climate Projections and Ecological Effects*

Purpose of Exercise = Compile a list of ecological consequences of projected climate changes for rivers/riparian/wetland systems, and discuss the relevance of those changes for the WY Statewide Habitat Plan.

CLIMATE DATA SOURCE: Projected changes in climate and hydrological variables by 2040-2069 relative to 1971-2000 are obtained from climatetoolbox.org; Mean values of RCP 4.5 (moderate emissions) are shown in Blue and RCP 8.5 (high emissions) are shown in Red; Model agreement = High (+) or High (-) (majority of models show increases or decreases); Medium (+) or Medium (-) (more than half the models show increases or decreases); Low (about equal number of models show increases or decreases).

Geography: Horse Creek watershed

Climate/ Hydrological Variable	**Future Projected Changes** *2040-2069 relative to 1971-2000*				**Ecological Consequences to Rivers, Riparian Areas, Wetlands**
	Range across all models + emissions	Mean RCP 4.5	Mean RCP 8.5	**Model Agreement**	
Mean Temperature (F)	Annual: +3 to +7 ºF Winter: +3 to +8 ºF Spring: +2 to +8 ºF Summer: +3 to +8 ºF Fall: +3 to +7 ºF	+4.4 ºF +4.3 ºF +4.2 ºF +4.6 ºF +4.3 ºF	+5.9 ºF +5.6 ºF +5.4 ºF +6.4 ºF +6.1 ºF	All models project increases	• Horse Creek is a unique stream system as it transitions from a cold water stream to a warm water stream throughout its course. In addition, Horse Creek has many diversions that influence connectivity and stream temperatures. These diversions not only divert water from the system, but some diversions add water to the stream. The section of Horse Creek that harbors the most diverse assemblage of fishes, is also the warmest. If this section warms, these fishes will need to move to find appropriate habitat. • September low flows when augmentation goes away = increased temps • Increased algal blooms? • Connectivity will be important • Increase in spread of nonnative bullfrogs.
Days w/ Heat Index > 90F *(5 days/year historically)*	Increase to a Total of 15 to 40 days/year	+22 days	+30 days	All models project increases	• Whereas mean temperatures may not become stressful for many native prairie stream fishes, hot periods where temperatures spike for 2-3 days at same time of low flows and low oxygen levels could be very impactful (and difficult to detect without extensive monitoring data) • Will an increase in increased air temps result in an increased demand for water based on new crops? • More rattlesnakes??
Precipitation (%)	Annual: -5 to +20% Winter: 0 to +40% Spring: 0 to +40% Summer: -15 to +10% Fall: -5 to +20%	+7% +15% +15% -2% +5%	+9% +25% +15% -2% +7%	High (+) High (+) High (+) Medium (-) Medium (+)	• With an increase in water volume moving through stream channels an increase in channel incision/erosion could occur if channels are denuded of wood and or beavers • Increased sediment
April 1 Snow Water Equivalent (%)	-50% to +15%	-20%	-30%	Medium (-)	• This drainage is a little more reliant on spring rain precipitation than snowpack, but with a reduction in snowpack will come a reduction in spring flows. This may make it an even more flashy system.

Growing season length (# days) *(historically 122 days)* **Growing Degree Days (F)** *(historically 5800 F)*	Longer growing season (+10 to +35 days longer) Increase in growing degree days (Total of 6300 °F to 8000 °F)	+20 6650°F	+26 7450°F	All models project increases	• GDD and growing season length influence on changing crop irrigation needs and water calls. • Potential for expansion and colonization by invasive riparian plants that would alter habitat and increase water demands • Greater GDD without corresponding moisture could result in rangeland plants/forage drying out early within the season and create decreased leader growth in fall browse species in the uplands, resulting in more impacts to the riparian system.
Evapotranspiration (%)	Spring: +8 to +22% Summer: -16 to +8% Fall: -2 to +14%	+13% -2% +1%	+16% -2% +1%	High (+) Medium (-) Medium (+)	• Lower potential groundwater recharge and flow maintenance during low flow periods.
Soil Moisture (%)	Spring: -1 to +11% Summer: -5 to +5% Fall: -4 to +5%	+4% 0% +1%	+5% +1% +1%	Medium (+) Low Medium (+)	• Increased sweet clover blooms, competing with native range plants
Intensity of precipitation events	High confidence for increases in the intensity of precipitation events, particularly the hourly precipitation rate at 3-7% per °F warming.				• Increased frequency of physical aquatic habitat disruptions • Properly functioning upland habitats can decrease the severity of flood events by capturing water in uplands, allowing for a slower release back to riparian systems. Native, perennial grasses + forbs can serve this function.
Flood frequency	High confidence for increases in springtime flooding (from increases in precipitation, increases in precipitation intensity, and rain on snow events).				• Driven by rain on snow events in late winter. Unknown what may happen if there is less snow in winter but more rain in spring. Erosion + downcutting? • Increased spring flooding and warmer temperatures leading to greater mosquito problem - leading to calls for pesticide use for control. Greater incidence of West Nile virus?
Drought	High confidence for increases in the intensity of future droughts; Propensity for increases in flash droughts (wet to dry in matter of weeks if there is a gap in precipitation).				• Decrease in upland water sources will create greater impacts on the riparian system from livestock and wildlife, creating increases on erosion, sedimentation, and impacts on riparian vegetation and fish habitat. • Could WGFD use their water rights for Bump Sullivan Reservoir be used as instream flows during periods of low flows in Horse Creek
Mountain Snowline	High confidence it will move up. 250 ft upward shift for every 1°F warming.				• Snowline may disappear from the headwaters of Horse Creek.

Streamflows					• Some info on potential changes in streamflow at the USGS Monthly Water Balance Futures Portal https://my.usgs.gov/mows/
					  ○ Use with caution, need to examine calibration results for this area
					  ○ Natural flows, does not include effects of irrigation/diversions
					  ○ Draft results indicate potential for lower seasonal flows July - September, increases in fall - winter
					• Could the stream use some in-stream flows to maintain suitable stream temperatures?

Geography: Yellowtail WHMA

Climate/ Hydrological Variable	Future Projected Changes 2040-2069 relative to 1971-2000: Range across all models + emissions scenarios	Mean RCP 4.5	Mean RCP 8.5	Model Agreement	Ecological Consequences to Rivers, Riparian Areas, Wetlands

Mean Temperature (F)	Annual: +3 to +8 F
	Winter: +3 to +8 F
	Spring: +3 to +8 F
	Summer: +4 to +8 F
	Fall: +3 to +7 F
		+4.6 F
		+4.5 F
		+4.5 F
		+4.9 F
		+4.3 F
			+6.1 F
			+5.8 F
			+5.7 F
			+6.7 F
			+6.1 F
				All models project increases	• *Stream temperatures will warm. Area supports warmwater fishes which may not be affected.*
					  • This warming trend will increase the noxious weed treatments and require additional time to treat
					  • Increased water temps may lead to eutrophic impacts or algal blooms in the reservoir

Days w/ Heat Index > 90F *(2 days/year historically)*	Increase to a Total of 6 to 19 days/year	+9 days	+13 days	All models project increases	• Could lead to certain wetland complexes drying out - stress on riparian avian nesting • Increased temperatures combined with potential increased nutrients from fine sediment, could lead to increases in HABs on lake.
Precipitation (%)	Annual: -2 to +15% Winter: 0 to +20% Spring: 0 to +25% Summer: -15 to +10% Fall: -5 to +20%	+6% +10% +13% -5% +8%	+9% +15% +16% -1% +9%	High (+) High (+) High (+) Medium (-) Medium (+)	• Increased precipitation could result in increased sedimentation, bank erosion, and flooding within the Shoshone and Big Horn Rivers ○ Maintenance could increase within the irrigation system as a result of increased sediment deposition. • Increased overland erosion could occur in ephemeral streams on the WHMA • Decreased summer precipitation may increase irrigation demands and contribute to river drawdown for agricultural interests • Increased spring moisture could delay crops from being planted and increase flooding • Changes in water management in reservoir drive changes in lake levels – consequences for vegetation in riparian areas and lake-margins
Growing season length (# days) *(historically 74 days)* **Growing Degree Days (F)** *(historically 4200 F)*	Longer growing seasons (+15 to +74 days longer) Increase in growing degree days (Total of 4700 F to 6250 F)	+41 days 5080 F	+52 days 5780 F	All models project increases	• Increased vegetation growth (stemming from increased precip and growing season) in the early months will probably result in more fuel load for summer fires • shifts in phenology of plants, consequences of mismatched timing of pollination, insect abundance, migrating wildlife (birds) (NS) • Increased growing season could result in change in crop and irrigation cycles throughout the Shoshone and Bighorn River basins. Senior water right holders may grow multiple crops in a season. Unknown consequences/endless • Increased GDD, combined with potential increased nutrients from fine sediment, could lead to increases in HABs on lake.

April 1 Snow Water Equivalent (%)	Decreased SWE (-28% to -7%)	-14%	-19%	High (-)	• Reduced SWE could lead to reduced water availability for irrigation and wetland/pond complexes having a negative impact on wildlife • Reduced SWE will reduce irrigation storage and knowing how much water will be available • Predictions of water supply more uncertain – potentially larger fluctuations in reservoir levels – opportunities for generalist riparian vegetation invasions.
Evapotranspiration (%)	Spring: +20 to +52% Summer: +2 to +10% Fall: +9 to +23%	+28% +5% +13%	+38% +6% +18%	High (+) High (+) High (+)	• Shallower wetlands/loss of surface water in wetlands in late summer- lack of habitat or even sinks for waterfowl and amphibians • Increased evaporation and possible increase in water level fluctuations could change soils, making increasingly saline
Soil Moisture (%)	Spring: +2 to +12% Summer: -12 to -4% Fall: -11 to -5%	+6% -7% -7%	+8% -9% -8%	High (+) High (-) High (-)	• Further degradation of riparian corridor along the Bighorn River Changes in native vegetation on uplands landscape. Increased grass density-combined with intensity of drought may lead to grass fires.
Intensity of precipitation events	High confidence for increases in the intensity of precipitation events, particularly the hourly precipitation rate at 3-7% per °F warming.				• Increased sediment runoff, particularly in spring months, could negatively impact fish spawning and egg survival in riverine species above and below the dam • Rapid rise and fall of ponds/res. - avian nest failures • Increases in fine sediment contributions, reservoir sedimentation, wetland creation at reservoir margins.
Flood frequency	High confidence for increases in springtime flooding (from increases in precipitation, increases in precipitation intensity, and rain on snow events).				• Increased flooding could result in sedimentation, bank erosion, and flooding within the Shoshone and Big Horn Rivers ○ Maintenance could increase within the irrigation system as a result of increased sediment deposition. • Flooding and sedimentation could accelerate the sedimentation of Yellowtail Reservoir and result in increased flooding on lands surrounding the reservoir • Cottonwood gallery regeneration issues due to timing and intensity of floods and droughts? • Increases in potential for upstream irrigation dam and infrastructure failures that may degrade aquatic habitats in the WHMA.
Drought	High confidence for increases in the intensity of future droughts; Propensity for increases in flash droughts (wet to dry in matter of weeks if there is a gap in precipitation).				• Flash flooding will increase maint.can cause sediment to deposit on vegetation • Change in species comp • Loss of floodplain connectivity and degradation of riparian corridor
Mountain Snowline	High confidence it will move up. 250 ft upward shift for every 1°F warming.				• Ungulates following spring growth may transition sooner, changing a variety of management practices and increasing need for a larger range of elevational habitat protections.

Streamflows		• Effects on flows during irrigation season in Big Horn and Shoshone Rivers? Potential effects on the Big Fork Diversion? Big Fork Diversion is the lifeblood of the north side of Shoshone - irrigation and wetland ponds. Could be a time in the future when irrigation season is going to change. • Loss of floodplain connectivity and degradation of riparian corridor

General notes from discussion (that don't fit into table above):

- From Eric's comments - Winter time flooding related to the reservoir levels? Spring flooding driven by snowpack in Shoshone. Not too much flooding from Big Horn. During high precip years we have localized flooding via the irrigation system. Spring flood events are not as widespread as they used to be. Our neighbor through the Shoshone had down cut at least 1-ft through their property in his lifetime. There's some dikes around the Cane town site that limit widespread floodplain flooding. The dikes outside of the reservoir floodplain are not affected by the reservoir levels. The oxbows have cut through some dikes.There isn't a lot of deposition along the dikes, water levels do not get up that high. Dikes near the confluence of Shoshone and Big Horn are silted in from sedimentation in the reservoir.
- Changes in temperature could have a profound effect on the way the reservoirs operate to meet irrigation demands. Could lead towards difficulty in predicting reservoir levels. Could affect the way wetland vegetation is recruited. Precipitation and intensity are expected to increase. Precipitation events are going to mobilize more fine sediment off the landscape and will create issues on the Shoshone for trout spawning habitat upstream and sedimentation rates in the reservoir. Temperatures could increase and due to sediment and temperature, those areas will be less suitable for trout and maybe some warm water fishes.
- Sedimentation could affect timing and quality of spawning habitat. Management of reservoirs could also affect this.
- End of irrigation wastewater goes into Yellowtail reservoir near horseshoe bend. Amount of water returned from our system is not significant enough to result in changes in the reservoir.
- Source water temperature at our diversion could be significantly increased due to irrigation return flows and warming/eutrophication. Could result in fish kills.
- If the watershed has longer growing season, people may be reusing the water more and could get decreased water at our irrigation diversion because of less return flows
- Differences in species composition could occur from shift in snow-melt to rainfall events. The increase in people wanting to hold water (adding reservoirs, holding ponds) could increase water temperatures or result in decreased base flows
- On big fork canal, we have more senior water rights, if and when we don't' have water...what will be the sentiment of our administration to put in a call for water

Geography: Spence and Moriarity WMA

Climate/ Hydrological Variable	**Future Projected Changes** *2040-2069 relative to 1971-2000*				**Ecological Consequences to Rivers, Riparian Areas, Wetlands**
	Range across all models+emissions	Mean RCP 4.5	Mean RCP 8.5	**Model Agreement**	
Mean Temperature (F)	Annual: +3 to +8 ºF Winter: +3 to +7 ºF Spring: +3 to +8 ºF Summer: +3 to +8 ºF Fall: +3 to +8 ºF	+4.5 ºF +4.4 ºF +4.8 ºF +4.8 ºF +4.4 ºF	+6.1 ºF +5.6 ºF +6.1 ºF +6.6 ºF +6.1 ºF	All models project increases	• Stream temps warming may allow other species to move in. • Warming stream temperatures may increase overlap between Rainbow Trout and Cutthroat Trout increasing hybridization risk • May increase growth rates of fish, currently cold temps slow growth • Increased susceptibility to disease (e.g. gill lice) • May need refugia for cold water fishes (deeper pools, more shade) ○ YSC may also move upstream into currently fish less streams? (US of East Fork of East Fork)

					• Will increases in temperature and precipitation regimes affect insect production and/or wildlife disease production? • Changes in insects and disease effects for plants (eg like pine beetle). • Groundwater recharge affected by evapotranspiration discharge points could be affected • Wet springs with hot dry summers may equate to increased grasshoppers
Days w/ Heat Index > 90F *(0 days/year historically)*	Increase to a Total off 0 to 3 days/year	+0 days	+1 days	All models project increases	• Concern for ungulates???

Precipitation (%)	Annual: 0 to +20%
	Winter: +5 to +20%
	Spring: +5 to +30%
	Summer: -10 to +10%
	Fall: -5 to +15%
		+9%
		+11%
		+15%
		-1%
		+6%
			+11%
			+16%
			+18%
			-1%
			+6%
				High (+)
				High (+)
				High (+)
				Low
				Medium (+)
					• Additional flooding concerns to infrastructure.
					  • More frequent channel migration?
					  • Need larger culverts on roadways for public access and reduce maintenance
					  • Flooding may blow out beaver dams
					  • Higher base flows and lateral habitat connectivity

Growing season length (# days) *(historically 42 days)* **Growing Degree Days (ºF)** *(historically 3050ºF)*	Longer growing seasons (+13 to +73 days longer) Increase in growing degree days (Total of 3470ºF to 4820ºF)	+42 days 3850ºF	+54 days 4450ºF	All models project increases	• May need more water for forage production for big game • Changes in forage and cover vegetation species, and even increased opportunity for non-native or invasive species such as undesirable annual grasses • Earlier warm-up may allow for invasive annuals to get an even earlier start and foothold • Potential for additional hay production
April 1 Snow Water Equivalent (%)	Increase in SWE (+1% to +18%)	+9%	+7%	High (+)	• More spring run off - more scouring of streams, movement of banks/channels

Evapotranspiration (%)	Spring: +5 to +32%
	Summer: +5 to +13%
	Fall: -6 to +3%
		+15%
		+8%
		-2%
			+22%
			+9%
			-1%
				High (+)
				High (+)
				Medium (-)
					• Reduced pond/wetland hydroperiod
					• More water required for irrigation purposes.
					  ○ May need to monitor instream flow to determine if min flow instream flow needs occur earlier in irrigation season (i.e., in 2012 irrigation in BC ended 7/5 while in 2014 it ended on 8/29)
					  ○ Potential loss of groundwater recharge.
					• Increase in windy days, leading to increased soil drying.

Soil Moisture (%)	Spring: +4 to +15% Summer: -6 to +3% Fall: -6 to +1%	+7% -1% -4%	+9% -3% -2%	High (+) Medium (-) Medium (-)	• Increased fire risk? • Warming may lead to increased drought stress in riparian communities and other adverse impacts to stream function

Intensity of precipitation events	High confidence for increases in the intensity of precipitation events, particularly the hourly precipitation rate at 3-7% per ºF warming.	• Increase in sediment loads to streams from upland erosion ○ Sediment deposition impacts to pool and spawning habitats • Increase in manpower to clean and armor infrastructure
Flood frequency	High confidence for increases in springtime flooding (from increases in precipitation, increases in precipitation intensity, and rain on snow events).	• Increased sediment transport/scour/deposition • Increased potential for impacts to instream/inditch infrastructure • Changes to channel morphology

Drought	High confidence for increases in the intensity of future droughts; Propensity for increases in flash droughts (wet to dry in matter of weeks if there is a gap in precipitation).	• Lower base flows, particularly late summer/fall
		  ○ Reduced fish abundance and biomass, reduced recruitment
		• Risk of increased fire intensity.
		• Shift in riparian communities from woody to herbaceous
		• Reduced riparian vegetation
		  ○ May interact with browsing
		• Drought may favor invasive species over natives
		• Reduced upland veg production, greater reliance on irrigated meadows, may reduce acres of hay cut
		  • Lower forage for ungulates

Mountain Snowline	High confidence it will move up. 250 ft upward shift for every 1ºF warming.	• Change use pattern for large carnivores (i.e. bears and moth sites) • Accelerated snow melt and instream flow impacts
Streamflows (including timing of streamflows)		• More variation in flows ○ Flow variation leading to seasonal habitat changes/availability • Instream flow filings within the watershed could become more important • Relationship of timing relative to irrigation needs • May need to look for alternative sources for irrigation water

General Notes from Discussion that doesn't fit into table above:

- Interaction of early season flooding and late season drought may negatively impact persistence of woody plants, leading to domination by herbaceous plants.
- How do all these climate variables affect water availability throughout the year?
- Big picture takeaway concerns:
  - Changes in volume and timing of water availability and in-stream flows
  - Physiological changes to streams - sediments, stream channel morphology
  - Changes in species community composition (fish- invasion by rainbow and brook trout supplanting yellowstone cutthroat, plant, insect- disease, parasite, etc) & subsequent impacts (disease, competition)
  - Changes in groundwater recharge

Geography: Bear River watershed

Climate/ Hydrological Variable	Future Projected Changes *2040-2069 relative to 1971-2000*				Ecological Consequences to Rivers, Riparian Areas, Wetlands
	Range across all models + emissions scenarios	Mean RCP 4.5	Mean RCP 8.5	**Model Agreement**	
Mean Temperature (F)	Annual: +3 to +8 ºF Winter: +3 to +8 ºF Spring: +3 to +11 ºF Summer: +3 to +8 ºF Fall: +3 to +8 ºF	+4.8 ºF +4.5 ºF +5.3 ºF +4.9 ºF +4.4 ºF	+6.5 ºF +6.1 ºF +6.7 ºF +6.8 ºF +6.2 ºF	All models project increases	• Stream temperatures will warm beyond tolerance levels for some fish species in some streams • From a fishes' standpoint, extremes matter more than means? if a river goes dry, they die • Duration of temperature extremes are also important. Many species can handle stressors of warmer temps but not for long durations. • Earlier spawning • Increased warming, either addressed in this box or in the 1st box, also increase the importance of maintaining connectivity for fish to access thermal refugia • Cooler spawning tribs, and connections to those, that retain ideal characteristics, become more important, same for spring inputs • More conducive to non-native fish species expanding distribution = competitive displacement. • Changing ice dynamics? - Might create more havoc in transitional areas = variability in ice dynamics
Days w/ Heat Index > 90F *(0 days/year historically)*	Increased to a Total of 1 to 9 days/year	+2 days	+4 days	All models project increases	• Suggest the potential need for angling closures where native and even key non-native fishes are targeted (sensu MT). ○ Other states are determining that angling pressure has no effect on fish populations during high summer temperatures. Likely a non-issue. • System vulnerability to cheatgrass, salt cedar, Russian olive
Precipitation (%)	Annual: -2 to +20% Winter: -1 to +20% Spring: 0 to +40% Summer: -15 to +10% Fall: -5 to +20%	+7% +7% +15% -2% +5%	+8% +10% +15% -2% +7%	High (+) High (+) High (+) Low Medium (+)	• Loss of ability to flood irrigate reducing wetlands. • More severe winter and spring events? Less predictable summer and fall precip? • Less flood irrigation will equate to less entrainment of fishes
Growing season length (# days) *(historically 63 days)* **Growing Degree Days (F)**	Longer growing season (+13 to +67 days longer)	+41 days 4580ºF	+51 days 5470ºF	All models project increases	• Plants maturing sooner, will quality forage be available later in summer/fall? If less soil moisture, increase evaporation, and potentially less summer precip is a longer growing season a good thing? - less vegetation or health in riparian area in late season? • An additional month to two months growing season? • Will this allow for better riparian habitat development to narrow stream widths? • Need for irrigation earlier and later in season

(historically 3800 F)	Increase in growing degree days (Total of 4400 ºF to 6080 ºF)				• From a fisheries perspective, longer growing seasons may allow for greater overall growth and the ability to compensate for metabolically stressful periods (if mortality doesn't occur) • Longer fire season
April 1 Snow Water Equivalent (%)	Decrease in SWE (-16% to 0%)	-8%	-10%	High (-)	• Earlier snow melt in the spring affecting reproduction of cottonwood and willows adapted to set seed and germinate later - Disrupted phenology • If snow not good indicator of moisture is -16 -0 an issue? What becomes new indicator?
Evapotranspiration (%)	Spring: +13 to +20% Summer: 0 to +13% Fall: +2 to +16%	+23% +6% +7%	+30% +6% +9%	High (+) High (+) High (+)	• Suggests the offsetting of any increases in precipitation and further stresses on reduced water supplies. • Increase chance of prolonged drought • Increased frequency of irrigation
Soil Moisture (%)	Spring: +1 to +9% Summer: -12 to -3% Fall: -10 to +2%	+6% -6% -5%	+7% -8% -7%	High (+) High (-) High (-)	• Reduced summer soil moisture spells need for beefing up "sponges" more intact wetlands, riparian plantings particularly in ag areas • Less available for plant growth
Intensity of precipitation events	High confidence for increases in the intensity of precipitation events, particularly the hourly precipitation rate at 3-7% per ºF warming.				• Large precip events have high erosive potential; places that are currently eroding will have even more pressure on the banks, riparian area, etc
Flood frequency	High confidence for increases in springtime flooding (from increases in precipitation, increases in precipitation intensity, and rain on snow events).				• Places with ongoing management issues = eroding banks, etc. may be susceptible to massive erosion. • Shifts in spring flooding also result in earlier peak hydrograph and reduced amount of water during the summer. • Along with increased precipitation intensity, this will increase sediment transport and start/continue shift to new dynamic equilibrium • Change in flood recurrence interval will change bankfull discharge. How do we determine restoration designs if we can't use historical bankfull discharges? • Loss of flood flows needed to transport sediment loads and promote stable channels. • Channel adjustments and plant establishment out of sync= instability • From Town of Bear River upstream, cottonwood recruitment is ok...but can't get established due to instability with sediment transport

Drought	High confidence for increases in the intensity of future droughts; Propensity for increases in flash droughts (wet to dry in matter of weeks if there is a gap in precipitation).	• Lower base flows, warmer water temps, limiting BRC habitat in Bear River proper, especially downstream from Evanston • Some reaches may go dry during base flow (• Can habitat modifications/restoration (e.g., structures that create deeper pools/low flow channels) allow fish to “hang on” through stressful periods. • Increased wildfire risk • Impacting upland habitats which can impact systems downstream - aspen/mixed mountain shrub
Mountain Snowline	High confidence it will move up. 250 ft upward shift for every 1ºF warming.	• Wonder if there are now any places that are “too cold” from BRC in the drainage, that might become better habitat under CC? Doubt it? • Affect aspen recruitment and increase loss of aspen to conifers. Potential to lose extent of key upland habitats
Streamflows		• Reduced stream flows → more instream manipulation for water withdrawal, further reduced connectivity • With reduced streamflows, a corresponding increase in entrainment due to increased proportion of streamflow used for irrigation. • Loss of reliable streamflow encouraging more water storage developments. • Decreased SWE, likely less summer precipitation, and higher need for summer irrigation will lead to more frequent and longer duration extreme low flows (e.g. flash droughts) • How and when were water allocations set for the watershed. • Cumulative loss of aspen, and loss of active beaver in 1-3 order tributaries • Reduced streamflows lead to increased density and lower growth of trout (drift feeders).

General notes from discussion that do not fit into table above:

- Cheatgrass development? Has huge implications for watershed health, fire risk, wildlife habitat, etc.
- Suitability for aquatic/riparian invasive species?
- Considering the relative status of riparian areas may be a means to consider how well the stream is connected to the floodplain and therefore allow for greater water storage and groundwater inputs. This may also facilitate native species within the riparian areas.
- Changes in snowpack/streamflow creating a desirable environment for tamarisk and Russian olive establishment and dominance. How else are these species affected by climate changes?
- Need to also consider how some of these factors interact (e.g., high temperatures*drought and the alignment of these more frequently)
- Pinyon/juniper encroachment on riparian areas - other states seeing this.
- Where does beaver activity fit into this; is a warming climate better or worse for them?
- What about relationship to ag practices, livestock management, and impacts of those changes on streams, riparian areas, and wetlands?
- Interstate water user issues related to the river flowing from Utah, into WY, back to Utah, and back into WY before heading downstream to Idaho

Filled-in versions of WORKSHEET #2 - Potential Measures of Relative Climate Vulnerability of Watersheds

All of the results from the Worksheet #2 breakout sessions from the workshop are captured in Tables 3 and 4 in the main body of this report.

Filled-in versions of WORKSHEET #3 - What's Different? Climate-Informed Management Approaches

Purpose of Exercise = Brainstorm ways that current management approaches might need to be modified to be effective in a changing climate, and new actions that might be needed to reduce climate change impacts and enable species and ecosystem adaptation.

Management Strategy or Family of Actions: Riparian Protection and Restoration

Current Management Actions	**In what ways might goals and/or actions need to be modified to be more effective in a changing climate? (Or indicate whether and why current strategies do not need to be modified)**			
	WHAT *New actions or modifications to current actions*	***WHERE*** *Take actions in locations that are strategic*	***WHEN*** *Change in the level of urgency or timing of actions*	***WHY*** *New or modified objectives that are forward-looking*
Re-vegetation of riparian areas	• Use riparian species that are well-suited for future climate conditions (including temp, precip, flooding frequency, etc.) • Increase funding opportunities to support the multi-year process of growing vegetation starts and getting them into the ground (eg. cottonwood deep pots) to increase capacity of restoration projects.	• Prioritize streams that are projected to retain perennial flows that can support riparian vegetation under future climate • Target restoration where increased flooding is predicted to reduce • sedimentation & run off (ag) • Target where greatest increase in heat predicted or where species vulnerable to heat to act as heat sink/cold water source	• Re-vegetation is urgently needed to stabilize stream banks before a big flood (which are becoming more likely)	• Riparian vegetation helps prevent erosion during floods, but also provides corridors for wildlife to move and track optimal climate conditions
Invasive species management	• Mapping prioritization of current areas • Consider vegetative intermediaries for highly impacted areas. • People/travel management • Tamarisk, RO, pepperweed, phragmites, leafy spurge, annual invasive grasses (cheatgrass, etc.), curlyleaf pondweed • Nonnative bullfrog expansion/control/containment	• Use resistance and resilience models to prioritize treatment areas that will have better chance of success. • Restore some flooding in regulated stream systems • Start high in watersheds with control or eradication efforts and work down • Areas where we can control water levels to drain ponds or allow to dry in winter to prevent	• Prioritize early detection areas for treatment where highest potential for success • Track infestations and their expansion through monitoring and assessment.	• Early detection and rapid response cheaper alternative than control of established infestations • Public outreach and education on identification, reporting, and mitigation.

		successful bullfrog reproduction in lowland/warm riparian areas ● Prioritize riparian systems that are unregulated and maintain the ability to flood.		
Fencing to protect domestic & wildlife grazing/browsing	● Create riparian management units to foster acceptance from grazers. ● Design projects that help guide livestock away from riparian areas (Zeedyk structures, mowing etc.) ● Add additional fencing capacity (more materials) ● Create upland water sources. ● Steel jack fencing and wildlife friendly fence designs. ● Work with other agencies on grazing management	● Evaluate priority areas ● Where opportunities develop with grazing managers. ● Support establishment of existing crucial and enhancement models	● Post-wildfire domestic grazing plans that are implemented immediately and are long enough to work properly ● New operators or new grazing management. ● Post-flood disturbances implemented immediately ● Eastern plains systems can be relatively free of snow in winter months allowing more herbivory on woody shrubs, tree seedlings. In combination with control of flows by dams on systems, it is difficult to regenerate woody species in riparian areas without additional exclusion practices. ● Evaluate season of use through monitoring and assessment as it pertains to changing climates.	● Protection of key areas for migrating species with high fidelity to their routes ● Allow continuing recruitment of desired plant species. ● Likely will be a more of a riparian zone dependency by ungulates as upland habitats dry and become less desirable. ● Protect what functional floodplains persist, particularly true in eastern WY. ● Fencing will allow for a mosaic of riparian patches resulting in instream habitat complexity (especially the further downstream you go and into prairie streams)
Raising water table/reconnecting floodplain	● Channel/valley grade control (undo channelization) ● Get SEO acceptance (fighting about water) ● Reconnect floodplains through mega-earth moving projects. ● Restore abandoned oxbows ● Transplant/restore beaver ● Use BDA and Zeedyk structures to raise water table and re-connect floodplain ● Remove upland stock ponds that capture water	● Where will SEO allow-promote flattening hyrdograph rather than earlier peaking hydrograph? ● Private landowners that are willing	● Maintain mid-summer base flows in streams by modifying irrigation practices ● Immediate post wildfire (thinking use of BDAs and Zeedyk structures)	● Restore sponges on landscape ● Increase canopy shading and structure
Adapt to increased flooding-earlier steeper hydrograph	● Retain water in tributaries longer ● Maximize water holding potential of uplands			

Targeted Beaver Relocation	• Use BRAT and other tools to prioritize locations for beaver restoration • Manage trapping regulations. • Educate about benefits of beaver. • Promote things like beaver deceivers and other devices to help landowners live with beavers	• Where there is sustainable willow, aspen, cottonwood habitat. • Where beaver don't become issues for downstream landowners • Appropriate stream gradient and power. • Compatible grazing management for quality woody riparian vegetation. • Begin high in the watershed and work downstream.	• After BDA installation, if appropriate. Plan in conjunction with BDA's	• Let the beaver do the work!
Maintain hydroperiods of off-channel wetlands	• Earth moving to increase depth of wetlands, • Shading	• Areas predicted to have increase drought and high evaporation rates (plains riparian systems) • Areas with multiple off-channel wetlands or wet meadows or playas that can facilitate population connectivity • Montane areas predicted to receive less snowpack		• Allow amphibians time to metamorphose. • Give amphibians time to potentially evolve to metamorphose faster (proven in some species but we need to buy them time) • Allow riparian ground nesting birds time to fledge (e.g. sandhill cranes, snipe)

Management Strategy or Family of Actions: Stream Restoration - hydrology and geomorphology

Current Management Actions	**In what ways might goals and/or actions need to be modified to be more effective in a changing climate? (Or indicate whether and why current strategies do not need to be modified)**			
	WHAT *New actions or modifications to current actions*	***WHERE*** *Take actions in locations that are strategic*	***WHEN*** *Change in the level of urgency or timing of actions*	***WHY*** *New or modified objectives that are forward-looking*
Bank stabilization	• Revegetating banks - Change the way will harvest willow - may need to seek a different source that is better suited for warmer conditions • Incorporate different plant species and/or more use of wood rock in places that are increasingly intermittent, or not wet enough to support sedges/willows • Design criterias will need to consider higher flows and flash flood conditions.	• Prioritize protection of spawning tributaries, maintaining corridors to access perennial habitats • Prioritize watersheds and streams that will be better able to maintain stability under increased peak flows and precipitation intensity	• Change the timing for harvesting willows or consider cold storage options for willows • Maybe also timing of planting	• Warming climate favors different species/varieties • Changing hydrography, stream power, flood peaks and timing

	• Will we need different approaches to stabilizing banks with bigger springtime flooding? • Shift to using larger materials to withstand higher stream power associated with flashy hydrography (engineered log jams i.e.)			
Reversing channel incision/ channelization	• Consider approaches that are cost-effective and allow for natural processes (where possible) to restore incision. • Consider the potential effects of beaver in upper parts of watersheds to mitigate quicker/earlier snowmelt and runoff • Take measures to protect and maintain connected floodplains (grade control, land management) proactively rather than have to work against odds to restore • Consider if incision is part of an autogenic process (occurs on a landscape in a cyclical time frame/ are natural processes) in subject stream. (e.g. arroyos are known to incise and then backfill within a decade, this occurs naturally)	• Use of remote sensing approaches to consider incision and where restoration actions are likely to have the greatest chance at recovery. • Ex: use NDVI to look at which streams are most resilient (then go look at streams that have good or poor resilience & determine what/if you can make areas more resilient based on characteristics of those that are resilient • Map locations where incision is likely to be a natural autogenic process that is not likely to be successful (arid/semi-arid) plains regions. • Predict where channel incision may occur in the future & determine what can be done to prevent it (prevention vs. treatment) • Prioritize protection of spawning tributaries, maintaining corridors to access perennial habitats • In areas where sensitive habitats or species occur. • Could result in the loss of sensitive habitats or species. • Areas with risk to health and human safety. • WGFC owned property • Larger scale, drainage wide restoration efforts (BDA, Zeedyk structures i.e.)	• Work to arrest head/downcutting earlier to avoid dropping water tables in drying climate regime • Important to initiate restoration when actions are possible to stop processes that led to incision (e.g,. Land use). • Has incision accelerated locally? Can it be directly related to land use? If so, mitigation should be part of the planning process. • Maybe scaling up the use of techniques like Zeedyk structures/BDAs (i.e., instead of doing 10 BDAs on one stream, do 10 BDAs on 10 streams in the same drainage)	• Incision is directly related to human activity on landscape. • Incision may reduce connectivity (laterally and longitudinally). • Channel incision mobilizes fine sediment locally. • May need objectives that are more proactive and involve more passive management, in addition to active (& involve other agencies/landowners more closely)
Purchasing/ pursuing in-stream flows	• Re-evaluate fish species based on where they may occur in the future when deciding which streams to pursue ISF rights • Consider legislation that provides framework for leasing of water rights and additional flexibility	• For cutthroat trout, prioritize stream segments where appropriate water temperature will occur, and beaver and resilient wetlands occur or can be established, and barriers to non-natives occur or can be established	• Need to secure ISFs as soon as possible to get ourselves in line of priority • Now	• Wildlife need water • Incentivise rather than legislate (where appropriate)e

	during years of extreme drought or heat. • Promote legislation that allows using traditional water rights temporarily for instream flow without losing priority • Increase efforts advocating for temporary change of use legislation • Look for funding partners and leaders • Pursue community efforts (like Healthy River Initiative in Lander) to involve water users on a voluntary basis & address water scarcity issues (recognizing that public education and positive involvement can be beneficial) • Build on TU's Upper Green River demand management approach	• Look more to cool water fish (sauger) and less trout waters • In general, prioritize stream segments that are in landscapes that are resilient and important for many aquatic, riparian, and wetland species • Could beaver restoration/conservation in streams where ISF rights are pursued be a good way to target using them? • Use results of water temperature models that incorporate flow in predicting water temperature. Calibration of stream-specific models may be appropriate in some cases		
"Two Stage channels"? "Multi Stage channels"	• Include low flow channels (channel within the channel) in design considerations to provide cover during low water period • Consider 4 stage channels in places with increasing flood frequency and risk to infrastructure - "urban" streams	• Areas that could result in the loss of sensitive habitats or species. • Areas with risk to health and human safety. • WGFC owned property		• Maintain instream flows, water depths and stream temperatures • Reduce risk of catastrophic flood where appropriate
Re-evaluate crucial areas in light of climate predictions		• Which areas are likely to maintain adequate temps/flows with Climate Change?		• Consider locations that are and are not resilient to climate stressors. This can be done via a variety of remote sensed, modeling, and local data

General notes from Discussion that do not fit into table above:

- Tools to help us understand what impacts may be – e.g., NDVI - greenness index, riparian area compared to valley width (or potential)
- May need regional focus for what to do (or species-specific)
- Focus on typing specific objectives to address specific hypothesized issues
- Need another management action added to table: "Environmental Commenting on Propose Water Developments" We need to increase our capacity to understand the consequences of proposed water developments and changes in water use on aquatic wildlife and communicate and negotiate effectively with developing and permitting authorities.

Management Strategy or Family of Actions: Fish Passage and Stream Connectivity

Current Management Actions	In what ways might goals and/or actions need to be modified to be more effective in a changing climate? (Or indicate whether and why current strategies do not need to be modified)			
	WHAT *New actions or modifications to current actions*	***WHERE*** *Take actions in locations that are strategic*	***WHEN*** *Change in the level of urgency or timing of actions*	***WHY*** *New or modified objectives that are forward-looking*
Replacing or improving function of stream crossings	• Replacing "standard" culverts/crossings with bottomless or fish friendly designs • Be sure to consider potential for increased flood flows/ flashiness. Current baseline is ~1.2 BF width. (USGS is working on understanding trends & working with DOT on that).	• Prioritize areas with more movement restrictions and species of concern	• Work with other agencies planning crossing maintenance or replacements to enhance fish passage	• Ability to freely move long distances allows fish to access various habitat needs
Removing barriers	• Install fish passage structures with consideration towards passing desirable species while excluding AIS/or non-natives on existing barriers to restore connectivity. • Work with stakeholders to remove barriers and undertake stream channel restoration efforts with species- and population-specific consideration to where barriers are removed. • Focus inventory efforts in drainages where climate change may impact flows and movements more immediately.	• Prioritize locations where barriers cannot be removed, but fish species connectivity restoration is desirable. Also consider species-specific requirements for barrier height, slope, etc. • Prioritize locations where water/land use practices can be altered and where barriers are in disuse or disrepair. Also consider where vulnerable fish population ranges will move in response to climate change and where barriers are in those locations rather than present barriers. • Focus on connecting entire watersheds where possible (i.e. Labarge Ck)	• Prioritize fish populations and species at the fringe of tolerances (temp, turbidity, etc.), where retained barriers cannot be removed and SGCN, vulnerable, or genetically unique groups are present/fragmented. • Should be prioritized for locations with fragmented SGCN or vulnerable fish populations and portions of watershed where population ranges may be found given impacts from climate change.	• Balance current water/land use practices with connectivity of fish populations to come to a stakeholder compromise. • Return river/stream to natural geomorphology and hydrology while connecting fragmented fish populations
Installing barriers	• Installing barriers to protect upstream native fish populations from invasion of non-natives (e.g. North Laramie, Sheridan Ck. = resist!) • May add urgency to preventing non-natives in certain places (BKT). • Niobrara - Pike - more floods equal more opportunities for invasion	• Focus in areas currently not impacted, most typical in the headwaters where the coldwater refugie exists • Places where you have unique genetics • Certain genetic stocks, uniqueness, may bear greater focus of efforts. Depends on additional information	• Identification of unique or vulnerable populations. • When chemical treatments are not feasible or likely to succeed at removing non-natives. • Increased urgency to installing barriers to get ahead of invasions that are happening more quickly because of warming.	• May be best or only option to preserve native species long-term(ns)

	moving up basin. Versus: Pearl dace at risk...stop resisting?			
Irrigation diversion rehab for passage	• Continue low vane and other approaches that promote passage of all species, year round • Use approaches that may allow passage for desirable species and prevent movement for undesirable species (more nuance to thinking specifically and individual spp. capabilities to prevent some and enhance others) • Determine if entrainment is a significant problem • Engineer to accommodate large and less predictable flows AND lower low flows. • Stream restoration in vicinity of passage work to best allow broad range of flows = multiple tier channels and wide floodplains. • Facilitate/ support stream stats development and use in fish passage and barrier work	• ??Same?? Where sensitive species benefit; most species benefit • Focus in areas where AIS (Brook Stickleback) or nonnatives are present	• Prioritize those that provide greatest amount of stream miles. Or, diversity of habitats? • Prioritize for areas with good habitats for important species (wild trout or SGCN) and lack undesirable species	• Is there a need to focus more on burbot in LR region? • Or other fringe species?
Enhance/restore streamflow	• Irrigation management • Watershed restoration • Stream restoration/reconnect channel/floodplain • Improve late summer/fall base flows • Use of Beavers	• Identify areas where critical streamflows might be decreasing due to climate change or other factors (land use, water use, etc.) • ID areas where enhancement might be possible	• Improved instream flow during low flow periods having most significant impact on aquatic habitat quality and availability	• Potential for purchasing water rights (narrow time window)
Identifying large-scale native fish restoration projects (GE)	• Reevaluate stream reaches feasible for long-term restoration success.	• Identify natural barriers • Expand and/or contract restoration reaches or re-site related barriers for streams most impacted by projected changes.	• Evaluate restoration projects with projections of climate effects on habitat over a realistic time-frame.	• Existing restorations may fail as climate change progresses. • Previously unacceptable stream reaches may become desirable.

Screening diversions	• Selective use in places with high amounts of fish loss to diversions	• Diversions in high priority watersheds supporting native species • Construct in fashion to accommodate perhaps larger flood flows or less predictable	• Consider the cost and water users willingness to take care of day to day maintenance (ns)	

General notes from Discussion that do not fit into table above:

- Identify / review research to apply information to specific locations to identify pinches in available range...distribution shifts in species range. Example Lodgepole Creek and Sweetwater River.
- One approach that seems to lack a home is translocation of remnant or imperiled fish, amphibian, native mussel etc species to refugia habitats. This category seems appropriate - maybe the title could reflect this, such as “Fish Passage, Connectivity, and Refugia.” (GE)
- Link to stream temperature is vital..need to understand the current and future conditions of water temps in order to best know where passage and connectivity is needed for various species. North PLatte River example.
- Tool to investigate potential future changes in streamflow - for stream segment or watershed:
  - USGS Monthly Water Balance Futures Portal
  - Use with caution - examine calibration results for the area that you are looking at!
  - https://my.usgs.gov/mows/ (Katherine Chase kchase@usgs.gov 406-439-9621 cel/406-457-5957 office for more info/demo of this tool)

Management Strategy or Family of Actions: Water Management on WHMA/WMAs

Current Management Actions	**In what ways might goals and/or actions need to be modified to be more effective in a changing climate? (Or indicate whether and why current strategies do not need to be modified)**			
	WHAT *New actions or modifications to current actions*	***WHERE*** *Take actions in locations that are strategic*	***WHEN*** *Change in the level of urgency or timing of actions*	***WHY*** *New or modified objectives that are forward-looking*
Irrigation	• Increased conversion of ditches to pipeline • Conversion of flood/gated pipe irrigation to pivots • Look at using beavers to help the irrigation processes naturally • Addition of fish screens to irrigation diversions where appropriate • Engineer/construct diversion structures to handle increased high flows and large stochastic events • Construct emergency spill structures on all irrigation ditches (wild, non-ID systems) • Increase settling ponds to handle increase in sediment loads from more spring rains • Change in crops species. • Move POD to areas less subject to flood damage	• Consider pipelines in areas where vegetation is not reliant on that water source or in ditch systems that seep more water then transport. • Build holding ponds in draws to decrease sediment shifts and increase water holding capacities. • Prioritize irrigation systems not within an irrigation district (e.g., Midvale) • Create ditches or flush systems that spread flood / flush waters onto dry plains. • Prioritize areas with more secure water rights • In WHMA’s in areas surrounded by intensive water use and management, it may be wise to	• Less irrigation water may be needed early and more later in the season due to shifting precipitation patterns • Pivot operations at night or when there is less wind drift and evaporation. • Use water when not competing with other demands (e.g. agricultural) especially to fill wetland areas • Increase early season holding capacity • Warmer springs may allow for earlier starts of irrigation season	• Depending on goals and staffing, being less efficient may be beneficial (resultant wetlands from irrigation seepage, “waste” water) • Shift to less water hungry crops due to reduced water availability • With increasing temps/evap, shift from irrigation to dryer native veg.

	• Proactively consider whether balancing forage or crop production and it's associated water use with depletions in stream systems is an appropriate strategy. We may have to consider writing off either the fishery or the irrigation.	decrease reliance on water, water infrastructure, or water rights.		
Wetland impoundments	• Reintroduce beaver to promote water retention • Promote conditions attractive to beaver colonization (willows, aspen, cottonwood etc.) • Update water impoundments/control structures to be able to control water levels • Store water in spring in higher impoundments for use later in fall migration for birds • Shift surface area to depth ratio for impoundments to reduce evapotranspiration loss • Increase canopy cover in riparian areas. • Use Zeedyk structures to slow runoff, improve infiltration for longer return flows • Increase capacity to move water (pumping systems) within a system to allow for wet soils management and to minimize evaporation loss from shallow ponds [mdp] • Implement/bolster beaver training program; establish "Beaver Academy"; recruit and graduate first class :)	• Prioritize important amphibian breeding ponds and migratory bird hotspots • Locations where recharge could occur/ could help late season flows • Consider extreme flooding events, avoid locations subject to being washed out • Secured/senior water rights locations	• Changes to timing to match migration shifts • Removing water in summer in places where evaporation and salinity are concerns • Move water from deeper to shallower wetlands to provide wetland habitat later in year	• Increase number of impoundments which could be used to hold spring rain water for irrigation later in the season • Where possible, consider more process based options
Water rights	• Increase pursuit, acquisition of water rights in both flowing and standing waters (both in association with WHMAs and also statewide) • Pursue legislation that provides flexible water management solutions • Monitor existing Instream Flow segments for compliance (not occurring now, will become greater need with more competition)	• Opportunistically statewide, around places where agriculture practices may shift and around municipalities • Target IF segments with intervening water users,		

***Filled-in versions of WORKSHEET #4** - Priority Climate-Informed Actions for Focal Watersheds/WHMAs*

Purpose of Exercise = Identify specific, climate-informed management actions for each focal watershed or WHMA (from Day 2 breakout discussions), that should be included in the draft revision of the Statewide Habitat Plan.

Geography: Yellowtail WHMA

Priority Climate-Informed Management Actions For Inclusion in the Draft Statewide Habitat Plan (SHP) Revision	**Briefly - Is it a new action? If not, is there any difference from current practice (eg WHAT, WHERE, WHEN, WHY)?**	**Notes (e.g., applicability outside of the focal area you are discussing)**
Invasive species management- Rapid response to new invasives	A lot has been here, never ending battle with knapweed, salt cedar, russian olives and a number of other species.	Being the downstream deposit zone, management upstream is required for any success for both aquatic and terrestrial invasives.
Protection and improvement of irrigation diversion and infrastructure	• Evaluate if upgrades are required to reduce flooding, sedimentation, or ensure that water rights can be captured from the Shoshone River. In response to changes in hydrology and sediment loads. • Our system capacity is currently less than our water rights.	• Do we need to look forward to potential flow regime changes to ensure that our infrastructure can capture water rights? • In other areas, consider diversion designs and management that would limit sediment from entering the systems.
Riparian Restoration - maintain high water table and cottonwood gallery through beavers, BDAs, wetland restoration	Some of this already. More needed.	
Sediment capture and stabilization	Overland erosion control measures may be needed	• BDA and willow planting in erosion-prone locations • Possible upland planting to hold soils together? Explore drought tolerant native species?
Irrigation efficiency	Some of this already: If applicable switching from flood irrigation to pivot or other more water efficient ways. Manage return water in efforts to reduce temp increases and maximize total system function, i.e return to river/riparian/wetland as soon as applicable.	These functions are beneficial system wide and can result in compounded returns if enacted.
Wetland restoration/ management	In progress, very large wetland complex	
Prevent unnatural overland erosion		Removal of unnecessary or unused two-tracks?

Enhance and maintain floodplain connectivity on Shoshone and Big Horn Rivers	Currently more of an issue on the Big Horn River. Deposition could be occurring in this area. Ice jams have removed dikes allowing oxbow connectivity. Needs further assessment to determine potential management actions.	Large river systems, could be complex and expensive

GENERAL NOTES FROM DISCUSSION (anything that doesn't fit into the table above):

- Meanders have cutoff on the Shoshone River and Big Horn. Entrenchment occurs after cutoffs. In backwater zones you'd expect movement for a long time. Ice jams can cause cutoffs.

Geography: Spence and Moriarty WHMA

Priority Climate-Informed Management Actions For Inclusion in the Draft Statewide Habitat Plan (SHP) Revision	**Briefly - Is it a new action? If not, is there any difference from current practice (eg WHAT, WHERE, WHEN, WHY)?**	**Notes (e.g., applicability outside of the focal area you are discussing)**
Range-wide genetic assessment of Yellowstone cutthroat to determine genetic variation/uniqueness of East Fork population	New, some genetic information has been collected but not compared to other populations across native range	Data needed for Wind/Bighorn drainage
Comprehensive inventory of natural fish barriers and water temperature in the watershed	In progress, but a bump in priority may be needed to complete task sooner	Statewide application
Evaluate water temperature (long-term datasets) throughout watershed and prioritize management based on species-specific tolerances.	Need for additional temperature monitoring stations to better track changes in specific streams. Start having better temperature data collection objectives than what we have been doing to help identify where to put loggers.	Statewide application
Inventory of invasive species, and development of treatment plans	On-going. Continue to gather science on best treatment practices.	
Irrigation efficiencies - change from flood to gated pipe and pivot • Flood irrigation can contribute to higher stream temperatures from return flows. Could switch to pivot irrigation in lower watershed and store more water (beaver, etc.) higher in watershed to keep water temperature lower throughout stream.	Nothing new on S/M, but not sure on other WHMAs statewide	May need to budget for alternative water sources
Emphasize floodplain reconnection with stream restoration to reduce impacts of future flooding.	Not new, but currently limited in use. Identify where opportunities exist for approach.	May be limited opportunities on S&M, but opportunities on other WHMAs?
Evaluate upper parts of drainages for beaver conservation/reintroduction. Consider long-term management (monitoring, trapping regulations?)	May require more effort & resources in terms of time devoted to trapping, facilities for holding groups, and new ways of transporting them.	Applicable statewide
Explore strategies to further work of trespass cattle exclusion from riparian area to maximize riparian function and resiliency		Politically charged

Monitor streamflow? Collect data to build on past flow monitoring to track significant changes in timing/amount/use. • Determine, recommend minimum • Help understand local processes in light of predictions	Not new - could be continued	
Monitor changes in vegetation species composition on winter ranges to ensure forage availability for wintering wildlife.		Also on Whiskey Basin
Conduct an exercise to look if management objectives of a WHMA would change based on climate projections	Maybe new??	Statewide

Geography: Horse Creek watershed

Priority Climate-Informed Management Actions For Inclusion in the Draft Statewide Habitat Plan (SHP) Revision	**Briefly - Is it a new action? If not, is there any difference from current practice (eg WHAT, WHERE, WHEN, WHY)?**	**Notes (e.g., applicability outside of of the focal area you are discussing)**
Strategically transplant beaver to areas that could benefit from increased water storage, aquifer recharge and floodplain connectivity.	We currently transplant beaver however transplanting with an emphasis on watersheds that will be affected by climate change is not occuring.	Applicable outside of this focal area
Much of this system is on private land, as such, work with landowners and grazing operators to maintain riparian health, monitor, and mitigate negative impacts. Work on grazing plans that can adapt to potential climate impacts.	Coordination with landowners is not new but important to continue to engage them especially in adapting to climate change.	Applicable outside of this focal area.
Use remote sensing to prioritize areas and landowners to work with and monitor changes.	Remote sensing to prioritize or focus on areas and landowners to work with is somewhat novel.	
Find reference reaches (both terrestrial and riparian) to base future habitat improvements on	Not a new action for higher elevation systems, but there is a need within these lower elevation systems	Applicable outside of this focal area.
Conduct widespread habitat assessments to determine riparian resiliency and appropriate diversity of habitats within the system.	We currently conduct habitat assessments however honing in on areas likely to be negatively affected by climate change does not occur.	Applicable outside of this focal area
Work on water management plan (overarching SE WY mgmt plan?) to determine if WGFD can use Bump Sullivan water shares for instream flows or wetland maintenance or fish production or pheasant production, etc Assess water use requirements / needs of landscape or drainage (crop, range, instream flow needs, wetlands, stock reservoirs, irrigation storage reservoirs).	Yes - completing this work sooner than later (when) to buffer future drought periods	Applicable outside of this focal area. Wick example too

Improve fish passage for SGCN by removing barriers and/or constructing fish ways at strategic locations that will allow movement currently and in the future to areas that may have suitable conditions (temp and streamflow) following climate change	We are working to improve passage currently but it is not necessarily strategic based on current or future instream habitat conditions	Applicable outside of this focal area.
Wetlands monitoring - continue, increase. Include monitoring of inflows, ET, water extents, etc. Use of remote sensing, in-situ equipment.	New/increased emphasis as water shortages might be more prevalent, need for water management.	Applicable to many areas
Planting of woody species to assist with shading of stream courses if water temps in reaches is an issue. May take 30-50 years to have significant impact. Woody species root structure also contributing to bank stability and prevent further downcutting.	Rarely used in this drainage.	Yes. Will require added protection from livestock and wild ungulates for success.
Utilization of USDA programs for stream course buffers in cropland areas. Potential for WGFD Trust Fund or other to cost share on practices.	Rarely used in this portion of Wyoming. Need to assess cost share rates, incentive payments, and USDA willingness to cooperate and sell their programs.	Yes. More suited to cropland environments.
Select sites that may be appropriate for construction of barriers now that will prevent upstream movement of non native species that are undesirable. This barrier(s) can prevent future interactions with SGCN that may be able to persist further upstream following climate change.	Rarely- Currently being implemented on N Laramie to prevent SMB expansion. If you build the barrier before native fishes colonize upstream, may require future translocations to these areas once conditions are suitable.	Applicable outside of this focal area.
Improve stream channel function where necessary to increase floodplain connectivity.	This is a current approach to stream habitat restoration, primarily in uplands and mountainous landscapes but more rarely used in lowlands and plains.	Yes. Applicable outside of focal area.
Long term “habitat easements” for riparian corridors, similar to a CE, but just for a specific habitat that would protect and enhance a riparian area for long term.	Yes and No. FSA has the CCRP program that is similar, but the longest an easement can take place is 15 years. Ideally, we would like to extend the length of this program	Yes
Incentivise habitat improvements with private landowners, find private landowner champions to highlight projects, and lean on partners (Conservation Districts, USFWS, NRCS) to take active role in habitat improvements. Potentially use wildlife species (turkey, whitetail deer, pheasant) instead on native non-game fish, to sell work.	Not new within Wyoming, but needed in prairie stream systems	Yes, applicable to many areas
Riparian fencing, vegetation mgmt actions aimed at benefiting terrestrial spp (with residual effects on aquatic species) - need to find ways to make conservation practices marketable to landowners	Could be marketed as “new”	Applicable in other places

Geography: Bear River basin

Priority Climate-Informed Management Actions For Inclusion in the Revised Statewide Habitat Plan (SHP)	Briefly - Is it a new action? If not, is there any difference from current practice (eg WHAT, WHERE, WHEN, WHY)?	Notes (e.g., applicability outside of the focal area you are discussing)
Prepare / plan/ identify ramifications of converting from flood irrigation to pivot or sprinkler in select areas, particularly around Cokeville Meadows	New action. May be research oriented or at least a data analysis exercise. Star Valley as example of area where has been converted to pivot recently. Partner with USFWS Partners Program/ CD's/ NRCS	Universal applicability, in places with flood irrigation.
Emphasizing watershed-scale work; prioritization/planning and scheduling frameworks that support more extensive work in fewer drainages	Not new, can stand to expand. Location/ sub watersheds?	Universal applicability
Identify senior water right user and sub divisions to inform of different water management regimes	? more of an education opportunity	Universally applicable
Conservation easements/In-stream flow to protect	Not new, perhaps begin to look more closely at the Bear River drainage	Universally applicable
Develop strategic, consistent, multidisciplinary approach to identify vulnerabilities of landscapes, riverscapes, and species; followed up with a systematic approach for combining vulnerabilities to identify highest priority areas for protection and restoration	New. This is comprehensive so it goes across state. Involves another process / working group to engage various and diverse players.	Universally applicable
Work with permittees and other agencies to promote sound grazing mgmt in the watershed to enhance resiliency of vegetation communities	Not new. More emphasis. Clear cut statements in certain cases.	Universally applicable
Connectivity focused stream restoration related to Great Basin Fishes	No. focus on spring creeks?	
Private landowner incentive programs for dry-land agriculture / selling unused water rights / etc.	As far as I know, not new	Universally applicable
Explore tributary drainages for suitable habitat to reintroduce beaver	More emphasis on identifying; hit all headwaters.	Universally applicable
Partner with and support groups that encourage smart growth/ retention agricultural open lands / control growth of subdivisions.	Not emphasized currently	
Angling closures related to water temperatures and flow conditions	~yes	Universally applicable for native fish and non-native fishes of interest for recreation.
Enhance spring creeks as potential cool water refugia - reconnect these systems		
Identify strains of fish permitted to be stocked that are possibly more adapted to warming water temperatures - gene infusion	No	Universally applicable

Staged Channels in the advent of higher flows and lower lows	Could be more explicitly called out as objective in restoration.	Universally applicable
Exploration of climate refugia-even outside of historic ranges (i.e., for imperiled species) that may serve as key source populations and allow for other limitations to be addressed		
Close areas to beaver trapping and transplanting beaver from lower in the watershed (if there are any);	Yes - Some areas	Universally applicable
Develop wet meadows and beaver complexes to increase water holding capacity on the landscape, presumably/hopefully delivery as well	Not really; requires coordinating with multiple entities.	
New parameters for design criteria		
Use flow, temp, and wetland resiliencies and importance to multiple species groups to help prioritize stream segments for instream flow water rights studies.	Have explicitly used temperature resiliency for cutthroat before. This would be an expansion to incorporate other factors and species to identify priority. Given instream flow statute, instream flow needs study would still be only on fish.	Universally applicable
Investigate opportunities to purchase water rights		
Develop novel ways of conducting large scale monitoring efforts efficiently (remote sensing, drones, loggers). Consider less monitoring in some cases.	evolving	Universal
Identify management options/projects that would positively impact systems below (aspen restoration)	Not new, but can work more collaboratively so that project ties into other projects within the same drainage.	Universal
Keep water in headwaters longer using natural approaches like beaver, BDA's, small rock dams (Zeedyk)		
Be aware of, and use agency programs (NRCS/ Farm Bill) to incentivize and facilitate water and wetland and riparian improvements.		
Enhance capacity to track water management opportunities and engage with State Agencies and legislature to promote Department water & other stuff		
Facilitate the development of a working BRAT model based off useful Landfire data and NHD PLus	Tried and failed in GR basin. Depends on accurate base layers.	

GENERAL NOTES FROM DISCUSSION (anything that doesn't fit into the table above:

- Bear River in area of Cokeville is in pretty tough shape; may be somewhat of sacrifice area for maintaining wetlands (cutting limbs off to save the body).

Appendix D - Detailed Information Needs

#	Information Needs (By Theme)	How useful is the information needs to your ability to consider the effects of climate change in your work on river, riparian, or wetland habitats? (# of responses)								Additional Details (e.g., for which species, which geographies, at what scale, etc.)	How Would Information Be Used?
	RIPARIAN & WETLAND ECOSYSTEMS	**Not Sure**	**Not At All Useful**	**Slightly Useful**	**Moderately Useful**	**Useful**	**Very Useful**	**Useful + Very Useful**			
1	Determine whether there is spatial variation across Wyoming in woody vs. herbaceous plant responses to changes in climate.	1	6	5	6	7	3	10	36%	Wyoming's diversity could lead to extensive variation in plant-type responses to climate change. Woody vs. herbaceous plant responses will have immediate impacts on the wildlife (big game, non-game, SGCN, etc) that rely on those species. Woody vs. herbaceous plant responses have impacts on the species that use these plants for food and cover. Understanding habitat shifts will help us understand wildlife vulnerabilities; In eastern WY, smooth brome dominates a lot of our riparian areas, and appears to limit deciduous woody plant recruitment. Some understanding where woody plant recruitment is occurring and where it isn't would help in determining the best places to restore.	In areas predicted to have major plant type changes, I would overlay that with Big Game seasonal ranges and see if I would expect future management changes due to changes in management objectives (i.e. carrying capacity), movements, harvest levels. If forage types change, eventually big game species distributions and resource availability will impact populations; Prioritizing woody species restoration projects.
2	Determine whether there are likely to be significant changes in synchrony related to cottonwood germination and growth success.	1	3	6	10	4	4	8	29%	In eastern WY, eastern cottonwood seems at high risk. Powder river drainage is probably the only really intact drainage right now for natural cottonwood recruitment, so if that were to change, I would imagine that everything else would suffer as well; Nesting raptors and Great Blue Herons; If needing to prioritize where this work takes place, cottonwood stands in NE and East-central Wyoming are very important for Golden Eagle nest sites (and can be the limiting factor for eagle density). Focus initial efforts there. Or prioritize by where the rate of change in relevant climate factors is predicted to be highest.	If significant changes are to occur, it is important to know where, so that mitigation can occur to protect our best galleries; Nesting raptors and landbirds; Inform cottonwood planting efforts, BMPs for landowners/managers on how to maintain cottonwood on the landscape.
3	Conduct habitat assessments to determine riparian resilience and appropriate diversity of habitats within the system (could include incorporating climate vulnerability into existing habitat assessment protocols).	1	4	5	6	5	7	12	43%	We need to remove our narrow focus and look at landscape scale; Knowing where and how to increase resiliency in riparian areas seems like one thing we could actually do to be successful in preparing for larger climatic changes; Even if a stream is far from perfect, getting a baseline for the current best of the best would be a great start for monitoring future changes in response to climate change; Nesting landbirds, raptors, and Great Blue Herons; We need this at a state-wide scale to inform prioritization of action.	This is going to help future managers to see what worked and did not when we gave it our best; Work with AHAB and THAB to increase resilience and diversity in areas that rank low resiliency through habitat assessments. Riparian areas are very limited in my region so their importance cannot be overstated. Riparian areas always provide incredible diversity, but that diversity is much more important when the relative diversity surrounding these areas is so low; Assisting with prioritizing habitat projects; Nesting raptors and landbirds; Inform our comments in land-use planning for land management agencies & outreach to private landowners; prioritize work and conservation areas; use in assessing SGCN status.
4	Investigate how different amounts of change in climate would lead to changes in a resource of interest (e.g., wetland area fluctuations in response to changes in precipitation).	1	3	5	5	10	4	14	50%	Are there better ways to manage wetlands with the change in climate and water availability at different times.	Prioritizing habitat projects; Could be used to change how we manage and adapt.
	BEAVER & OTHER PROCESS-BASED RESTORATION APPROACHES	**Not Sure**	**Not At All Useful**	**Slightly Useful**	**Moderately Useful**	**Useful**	**Very Useful**	**Useful + Very Useful**		**Additional Details**	**How Would Information Be Used?**
5	Determine how process-based restoration approaches (e.g., beaver dam analogs, beaver, Zeedyk structures, etc.) affect the timing and quantity of water delivered to downstream water rights holders.	2	3	3	3	8	9	17	61%	Use real beaver dams as a potential surrogate for BDAs; This is an area of contention with the State Engineer's Office; thus, research could be done with them to ID places to test theories about impacts on senior water users; Nesting Trumpeter Swans; Studies quantifying the efficacy of these trendy treatments are needed.	Learning experience; Where to relocate beaver, how runoff timing will change fish migrations; This would be influential in working with the SEO and policy makers in approving permits for restoration work; Information for political "battles" regarding process based restoration approaches; Nesting Trumpeter Swans; This would go a long way towards helping conversations with State Engineer's Office and regulatory agencies, streamlining permitting and planning, allowing us to get more done.
6	Determine how process-based restoration approaches (e.g., beaver dam analogs, beaver, Zeedyk structures, etc.) affect shallow alluvial aquifers and riparian areas.	2	2	3	6	8	7	15	54%	Generating facts and examples about water storage using a BACI design would help understand the impact this work can have on water storage and riparian health. Would be good to pay close attention to the valley type, geology and other factors. Might target a "moderate" size valley and other parameters to yield info that is likely to be transferable to ongoing work; Nesting Trumpeter Swans and landbirds.	Learning; This would be influential in working with the SEO and policy makers in approving permits for restoration work. Also, this would be useful for helping to apply the right tool in the right place and know how much effect to anticipate; Information on how effective these tools are at assisting WGFD at reaching their goal; Nesting raptors, landbirds, and Trumpeter Swans.
7	Develop an up-to-date and accurate BRAT (Beaver Restoration Assessment Tool) model.	2	5	3	8	6	4	10	36%	Need less paperwork on this. Too many hoops to jump through.	If time allows; Assists in helping WGFD prioritize beaver translocation.
8	Assess beaver translocation success or failure to determine what drives survival and establishment of colonies, and understand spatial variability.	1	2	5	4	8	8	16	57%	Agency needs equipment/staff to translocation to be successful; Beaver translocation work seems to be more and more popular, with more effort needed. However, knowing how to make a translocation successful would obviously increase our ability to do efficient and effective work. In many cases, I think a successful beaver translocation is a sign that the watershed is already on the mend or not "too far gone". Learning what might be prohibitive to beaver translocation success may help set the groundwork to work towards conditions that would be amenable to a successful translocation effort. To me, beaver absence is a huge red flag for a watershed and I worry about the compounding impacts on big game, non-game, and SGCN species in areas with historic but no current beaver activity.	Currently do; Assuming that my area of responsibility would have high failure, learn the determining factors so we can improve those conditions and turn an area that would have low success rates into an area with high success; Allows to better know when beaver translocations are worth doing or not to meet habitat goals.

	AQUATIC HABITAT & FISHERIES	Not Sure	Not At All Useful	Slightly Useful	Moderately Useful	Useful	Very Useful	Useful + Very Useful		Additional Details	How Would Information Be Used?
9	Conduct site-specific studies of base flows needed to allow fish survival during periods of high water temperatures.	0	1	7	8	6	5	11	41%	Should be done across the state. Prioritize sampling reaches with SGCN & native sportfish. This should feed into the inventory of water temps; Needed for game fish so regulation can be put in place to shut down fishing when water reaches certain temps.	Need more recording devices; Work on in-stream flows to protect this.
10	Determine thermal limits for specific species.	0	3	6	5	9	4	13	48%	Better identification of thermal limits for native non-game.	Better understand conditions where we may see population declines; Set regulations that close fishing based on stream temps to protect fish
11	Develop an inventory of water temperatures by watershed and prioritize management based on species-specific tolerances.	0	1	9	3	10	4	14	52%	To allow future planning for changes in fish species changes and how it may change stocking plans and hatchery planning; Seems that we have decent data, monitor in other watersheds not previously sampled that overlap with key species seems to be a first step to further improve our data collection; Focus on SGCN and native sportfish.	For planning of when to stock fish and when it may be too early or late due to water quality (temp and PH) and species that will tolerate changes; Where to focus passage work; Inform our comments for land-use plans for land management agencies.
12	Develop fish habitat models that incorporate climate variables into stream suitability/vulnerability analyses for species and assemblages; Identify streams that could become suitable under future climate scenarios.	0	3	5	2	13	4	17	63%	This is important for future range-expansion and restoration of native cold water fishes; Select Tier 1 SGCN fish & herp species.	Native species range expansion projects; The part about streams becoming suitable is the key. Knowing these would help us plan proactively.
13	Conduct a range-wide genetic assessment of Yellowstone Cutthroat Trout to determine genetic variation of populations to guide future protection and management actions.	0	9	3	5	7	3	10	37%	I think this is the most important potential project that can be conducted to guide future conservation and restoration of Yellowstone Cutthroat Trout; Already underway?	Determine what YSC populations have the highest conservation value (based on genetic purity and which YSC populations are indigenous (higher conservation value) vs. stocked). Learning more about these populations will guide future conservation and range expansion projects. This project may also assist with more successful range expansion projects by determining which genotypes survive better in different habitat types (e.g., high vs. low-elevation systems)
14	Determine whether there are likely to be significant changes in synchrony between native cutthroat trout spawning and changing water temperatures and runoff timing.	0	5	4	5	7	6	13	48%	Snake Watershed; BRC, YSC, CRC - in that order; Nesting raptors; Also important for SGCN.	Better understand how runoff timing changes impact cutthroat trout; We have a system of 404 permitting with the COE that incorporates spawning dates...these may need adjused; Nesting raptors.
	CLIMATE REFUGIA, PRIORITIZATION & PLANNING	**Not Sure**	**Not At All Useful**	**Slightly Useful**	**Moderately Useful**	**Useful**	**Very Useful**	**Useful + Very Useful**		**Additional Details**	**How Would Information Be Used?**
15	Identify climate refugia (within and outside of historic range) for imperiled species that may serve as key source populations and allow habitat limitations to be addressed.	0	2	5	4	9	8	17	61%	I equate this to our Crucial range designation for Big Game species, however on a larger and longer scale. The importance of identifying refugia areas for both imperiled and non-imperiled species needs to be identified ASAP so protections can be put in place if needed. Also, so we can learn what attributes make these area refugia and potentially increase refugia area footprints through management; Native cutthroat; Nesting raptors, colonial waterbirds, secretive marshbirds, and Trumpeter Swans.	How to increase movement opportunities within the refugia areas; I equate this to Big Game Crucial Range. Depending on the species, perhaps WGFD comments on development or prioritization for habitat improvement projects could take areas of refugia into account for protections and habitat management support; Could ID protective approaches (IF water rights, property rights); Information about places to focus on protecting in case climate change does drastically affect current habitat; Nesting raptors, landbirds, colonial waterbirds, secretive marshbirds, and Trumpeter Swans.
16	Identify potential translocation sites for species of conservation concern that consider future climate conditions not just current climate conditions.	0	1	5	7	9	6	15	54%	For native non-game species on the fringe of their range; Horny head chub, native cutthroat.	Utilize translocation sites to protect native non-game into the future; Need to focus on landscape scale; This would allow us to be proactive and move species before they get to a critical stage; Information about places to focus on protecting in case climate change does drastically affect current habitat.
17	Develop a standardized, systematic protocol for evaluating and prioritizing watersheds for protection and restoration as related to climate change, that considers both aquatic and terrestrial needs.	0	1	6	6	6	9	15	54%	Nesting raptors, colonial waterbirds, secretive marshbirds, and Trumpeter Swans, and landbirds; Consider SGCN amphibians, wetland birds, wet meadow terrestrial wildlife (curlew, Preble's meadow jumping mouse) as part of terrestrial needs. Where would habitat be lost if water efficiency means the loss of flood irrigation?	Help to prioritize work areas; Habitat management prioritization; Nesting raptors, landbirds, colonial waterbirds, secretive marshbirds, and Trumpeter Swans.
18	Analyze management objectives of Wildlife Habitat Management Areas (WHMAs) relative to climate change predictions.	0	2	8	4	6	8	14	50%	Work on long term plans and get staff on same page; Pick a subset with significant water: Table mountain, S&M, Grizzly, Yellowtail; Nesting secretive marshbirds and landbirds; More detailed climate-informed management prescriptions are needed - refine scale by geography, species, or resource issue. A focus on WHMAs is welcome; Can climate change be incorporated into management.	In progress; Our habitat biologists could take smarter actions today if they look ahead at where each WHMA is likely headed; Assess current utility in meeting objectives; Nesting secretive marshbirds; Help with prioritizing work schedule items; Could possibly change how these areas are managed, maybe different plant species will be used, update irrigation systems, etc.

#	CLIMATE CHANGE VULNERABILITY ASSESSMENTS	Not Sure	Not At All Useful	Slightly Useful	Moderately Useful	Useful	Very Useful	Useful + Very Useful		Additional Details	How Would Information Be Used?
19	Conduct species-specific climate change vulnerability assessments at local scale (e.g., within wildlife habitat management areas or sub-watersheds).	0	2	7	6	9	4	13	46%	Key willow spp., cottonwood, cutthroat in S&M, Grizzly WHMA's; Would be great to have a list of all avian nongame species on WHMAs.	Use in changes of water usage, and future weed spraying practices; Nesting raptors, landbirds, colonial waterbirds, secretive marshbirds, and Trumpeter Swans.
20	Conduct species-specific climate change vulnerability assessments at regional scale (e.g., within large watersheds).	0	3	5	7	12	1	13	46%	Understanding how/where imperiled and non-imperiled species may become limited or vulnerable is our mission: Conserve Wildlife. Period. Also, similar comment to [earlier question] I equate this to our Crucial range designation for Big Game species, however on a larger and longer scale. The importance of identifying refugia areas for both imperiled and non-imperiled species needs to be identified ASAP so protections can be put in place if needed. Also, so we can learn what attributes make these area refugia and potentially increase refugia area footprints through management.	This is the only way for me to know if the species that I manage will be vulnerable to climate change. This is similar to understanding how wildlife species are vulnerable to disease or development because it could have major long-term impacts to population viability. Once again, it goes right back to our mission.
21	Conduct species-specific climate change vulnerability assessments at the statewide scale (e.g., assess climate change vulnerability of all WHMAs or sub-watersheds across the state).	0	4	9	4	5	6	11	39%	Understanding how/where imperiled and non-imperiled species may become limited or vulnerable is our mission: Conserve Wildlife. Period. Also, similar comment to [earlier Q] I equate this to our Crucial range designation for Big Game species, however on a larger and longer scale. The importance of identifying refugia areas for both imperiled and non-imperiled species needs to be identified ASAP so protections can be put in place if needed. Also, so we can learn what attributes make these area refugia and potentially increase refugia area footprints through management; Cutthroat, key herps at all WHMAs; It's very important to consider both species-focused and place-focused approaches. Which places will be the most vulnerable, but even moreso, which SGCN at the state-wide scale (aquatic & terrestrial) are most vulnerable to climate change.	This is the only way for me to know if the species that I manage will be vulnerable to climate change. This is similar to understanding how wildlife species are vulnerable to disease or development because it could have major long-term impacts to population viability. Once again, it goes right back to our mission; Use to inform commenting on priority species, locations, actions for land-use planning by land management agencies; Information could provide insight into the change climate and better ways to protect what we have.
22	Develop database of species-specific tolerances of changes in climate.	0	3	4	5	7	8	15	56%	For native non-game; The HUC 10 level seems to be reasonable. Focus on species in the SWAP; The more we catalogue and understand habitat and species tolerances, the more likely we will be able to find ways to help build resiliency so they can adapt and survive; Need this for all SGCN to feed into vulnerability assessments, but could start with those with most restricted range, narrowest habitat tolerances, least mobile, slow reproduction (K-selected); Base this off of the previous answer [assessing climate vulnerabiliy at the state-wide scale]	Better understand what species are most at risk and prioritize them; This would help me prioritize how to manage based on tolerances as well as which species have more or less viability and therefore priority based on their tolerances; Nesting raptors, landbirds, colonial waterbirds, secretive marshbirds, and Trumpeter Swans; Use to inform BMPs & disseminate those to resource managers, landowners; We may need to look at using different species in the future.

#	INVASIVE SPECIES	Not Sure	Not At All Useful	Slightly Useful	Moderately Useful	Useful	Very Useful	Useful + Very Useful		Additional Details	How Would Information Be Used?
23	Determine which invasive species we might expect to see that are not yet in Wyoming.	0	2	3	4	11	8	19	68%	Statewide; Include upland species too, not just aquatic. Also, how these species are shifting within the state would be good; More invasive annual grasses, statewide scale;	Inform partners and landowners in these potential areas about these species so that we can get ahead of them before they become a problem; Nesting raptors, landbirds, colonial waterbirds, secretive marshbirds, and Trumpeter Swans; This could be used for invasive species prioritization. We never have enough funds to cover everything, so this could help; Incorporate into our invasive plant and animal strategies to prevent intro, and treat where found. Add comments to guidance letters sent to agencies, developers, permitters; Being ready to eradicate when these show up.
24	Determine whether there are likely to be significant changes in synchrony favoring Russian olive and salt cedar.	2	3	5	9	6	3	9	32%	Systematic and complete removal of these invasive species is preferred.	Nesting raptors, landbirds, and colonial waterbirds.
25	Investigate relationships between invasive plants and invasive fish species to understand potential management actions.	1	2	4	10	8	3	11	39%		
26	Analyze the existing and potential future location of barriers in key watersheds relative to keeping native and non-native fish species apart.	1	1	6	4	7	9	16	57%	I think keeping native species separated from harmful nonnative species is sometimes overlooked, both when proposing projects to create fish passage, and in overall project prioritization.	Upkeep or installing of water barriers to protect native fisheries; Prioritize creation of new barriers or maintenance and enhancement of current barriers to keep native and harmful nonnative species apart.
27	Identify management or habitat actions that disadvantage invasive fish and plant species.	0	2	3	3	10	10	20	71%	Management actions against brook trout; Shut down more roads to the public that have a high probability of introduced species. Is fire the answer for everything so we can increase the Cheatgrass through out the state?	Currently do and this is why we are moving away from out of control burns; Using the best practices approach in order to keep landscapes from degrading; Nesting raptors, landbirds, colonial waterbirds, secretive marshbirds, and Trumpeter Swans; Use in our management actions and provide as guidance to resource managers and landowners (via HPP & regional outreach).

	FISH PASSAGE & STREAM CONNECTIVITY	Not Sure	Not At All Useful	Slightly Useful	Moderately Useful	Useful	Very Useful	Useful + Very Useful		Additional Details	How Would Information Be Used?
28	Develop or adjust design criteria for fish passage structures and culverts to account for larger floods and lower base flows.	3	1	5	4	6	8	14	52%	Need to prioritize this as we all know funding and staff is needed to complete; This is easy to adjust, but what to adjust it to is the question. Climate models that could provide better scenarios would be helpful; Do this for each of the USGS hydro physiographic provinces...Or, at least inform it by channel slope, valley form, and predicted sediment supply; Set a new standard for design.	Incorporate updated design criteria; This would feed right into the design specs for culverts, road crossings, and other passage projects; Coordinate via HPP to have other relevant agencies (WYDOT, feds) and permitting bodies (county governments, DEQ, etc.) adopt those design criteria; This may be the future so we should be designing for it.
29	Develop a statewide climate-informed stream connectivity assessment.	2	6	3	3	8	5	13	48%	Interpret connectivity for all age classes of all fish species; Nesting raptors and Trumpeter Swans.	This would help prioritize where we spend our time and funding. Places that are connected would be places we'd work to protect. Places lacking connectivity require targeted projects that the assessment would help illuminate; Nesting raptors.
30	Develop an inventory of natural fish barriers.	3	2	3	6	6	7	13	48%	Yes and could be easy with collector app on smart phone.	
31	Project future instream habitat conditions (to prioritize fish passage projects).	3	3	4	4	8	5	13	48%		
	HYDROLOGY & WATER BALANCE	**Not Sure**	**Not At All Useful**	**Slightly Useful**	**Moderately Useful**	**Useful**	**Very Useful**	**Useful + Very Useful**		**Additional Details**	**How Would Information Be Used?**
32	Determine water holding capacity in shallow alluvial riparian areas, as a function of different valley forms, geology, land use, and vegetation characteristics.	1	4	7	3	8	5	13	46%	There are 2 major "return flow" studies I am aware of in Wyoming (New Fork and East Fork Wind by Bea Gordon). The results span a range of time periods for seeing the return of water applied to the surface. Expand on these by conducting work in other areas with different conditions.	Currently working on this; By putting numbers to this, we could negotiate with other water users and agencies to partner more effectively to store water underground rather than in surface reservoirs where it is readily lost to evaporation; Inform managers on what we can expect given any type of habitat treatment.
33	Understand how upland habitat treatments (juniper removal, sagebrush mowing, etc.) link to water release into the watershed and system impacts with more intense precipitation events.	1	3	3	3	9	9	18	64%	Basically we need to know if changes in ground cover translate to greater or lesser water delivery from basins... probably at the 100s to 1000s acres scale; This is very important and bridges the Fish and Wildlife Division, therefore frequently does not get accounted for or recognized.	Proving this with MDI work; Inform managers about costs/benefits of upland vegetation treatments and how it relates to their goals; It would be valuable to understand how upland treatments would affect water delivery to streams or wetlands to either compare trade offs or find win-win solutions; Understanding how THAB projects can influence water systems is a way to integrate multiple work programs and more efficiently work between Divisions; Develop BMPs and communicate those to land managers and owners; Could impact where and how we do habitat treatments.
34	Investigate resiliency and impacts in different hydrologic provinces: e.g., Snowmelt vs. non-snowmelt prairie streams.	1	3	7	5	9	3	12	43%		Informs managers about how different types of systems will be affected in a future climate to allow us to prioritize/manage habitats differently if needed.
	STREAM RESTORATION	**Not Sure**	**Not At All Useful**	**Slightly Useful**	**Moderately Useful**	**Useful**	**Very Useful**	**Useful + Very Useful**		**Additional Details**	**How Would Information Be Used?**
35	Identify places with higher future risk of flooding to prioritize floodplain reconnection with stream restoration to reduce impacts.	0	2	6	4	11	5	16	57%	Nesting Trumpeter Swans, especially in NW Wyoming.	Nesting Trumpeter Swans.
36	Predict future bankfull discharges and sediment transport resulting from increased peak flows and precipitation intensity, for use in stream restoration design.	1	4	5	4	9	5	14	50%	Conduct this work in different hydro physiographic provinces (Mountain, Basin, Prairie)	In some locations bank full discharge or high sediment discharge results in complete changes in the landscape and can be damaging to plants and fish; Implicit in the statement...would be used in design of stream restoration. Bankfull is a key design parameter.
37	Develop prairie stream Best Management Practices (BMPs) for habitat enhancement given predicted climate changes.	0	3	4	8	6	7	13	46%	Lodgepole Creek, Horse Creek; Nesting raptors, especially in the eastern half of Wyoming.	We could share these with landowners and also use them along with the NRCS and Conservation Districts; Allows us to make sure we are making the right decision in the face of climate change; Nesting raptors and landbirds; Communicate these to land managers and owners.
38	Collect reference reach information at existing functioning prairie stream sites to provide a template for restoration.	1	2	9	4	9	3	12	43%		Allows evaluate which prairie streams are at risk and how far from functioning, which will allow for basin restoration prioritization.

	WATER MANAGEMENT	Not Sure	Not At All Useful	Slightly Useful	Moderately Useful	Useful	Very Useful	Useful + Very Useful		Additional Details	How Would Information Be Used?
39	Explore the feasibility of capturing water runoff from irrigation and recirculating for further use.	0	1	8	7	6	6	12	43%	And hope the reduction of fertilizer helps downstream ponds or other sources; Water, water, water. Everything we can do to conserve water, in all ways, at all times, for all species, including humans; Nesting colonial waterbirds and secretive marshbirds; This is already being done in some areas.	Work with landowners to better understand water use impacts to wildlife habitat and wildlife; If feasible, could be used in a watershed that is already limited in water flow due to irrigation; Nesting colonial waterbirds and secretive marshbirds; Could use for wetlands like we do at Ocean Lake in the NW wetlands.
40	Develop a better understanding and examples of tradeoffs for water use and wildlife benefits for flood versus pivot irrigation.	0	2	2	6	9	9	18	64%	Water, water, water. Everything we can do to conserve water, in all ways, at all times, for all species, including humans; Bear River at Cokeville Meadows compared to Bear River upstream of Evanston; Wick WHMA; Table Mountain WHMA; Need to know how to maximize water use for the benefit of wildlife. For example, does conversion to sprinklers not support wetlands and valuable return flows. I think this would be most valuable in relatively small basins (smaller than the Bighorn or Platte Rivers); Consider Long-billed Curlew and other wet meadow/irrigated meadow using SGCN.	Work with landowners to better understand water use impacts to wildlife habitat and wildlife; Internally we would be wiser as we contemplate converting to pivots. We could also work better with partners like Trout Unlimited; Provides us better information where and when pivot irrigation is warranted, which in turn will allow the department to push for one or the other when appropriate; Nesting colonial waterbirds, secretive marshbirds, and Long-billed Curlews; This would have implications for how hard we push for or against these conversions with commenting or working with water users.
41	Analyze tradeoffs between managing water use for instream vs. out-of-stream habitats (e.g., wetlands) (i.e., determine habitat and ecosystem function gains and losses per cfs).	0	2	1	7	10	8	18	64%	Bear River at Cokeville Meadows compared to Bear River upstream of Evanston; Wick WHMA	Finding the best use per cfs for each particular area for the best use of the limited water; We are collaborating with the IMJV, WNTI and others on the Bear River. This is a place that has both approaches and offers a potential playground to analyze tradeoffs; Future water management.
	BASELINE DATA & MONITORING	**Not Sure**	**Not At All Useful**	**Slightly Useful**	**Moderately Useful**	**Useful**	**Very Useful**	**Useful + Very Useful**		**Additional Details**	**How Would Information Be Used?**
42	Develop novel methods for conducting large scale monitoring efficiently (e.g., remote sensing, drones, loggers) and consider less monitoring in some cases.	2	0	6	10	5	5	10	36%	We need corresponding people with big data study design, management & analysis expertise - specifically a quantitative ecologist/biometrician on staff to support, coordinate, standardize these efforts across the state. Will save resources and be most efficient.	Become more efficient at monitoring.
43	Increase streamflow and wetlands monitoring to build on historic monitoring and track changes in water quantities, timing and use.	2	0	7	6	12	1	13	46%		
44	Develop statewide stream and riparian condition information depicting departure from expected conditions stratified by valley type, slope, and physiographic province - to indicate where streams are most degraded or furthest from functioning.	1	2	8	8	6	3	9	32%	This information would be directly related to existing stream condition; NFHAP did a national assessment that was based on secondary factors (distance to roads, cities, amount of development in basin, etc). This assessment could include Rosgen stream class, LIDAR derived information about channel incision and obstructions, and riparian plant species and condition perhaps from LandFire; Use existing nongame geodatabases.	We could better track progress in restoring streams; we could communicate better about where the biggest issues occur; we could better prioirtize proposed projects (or develop them) based on their location relative to stream condition; Nesting raptors and landbirds; Prioritize restoration and protection actions for us and other land managers/owners.
	NEW INFORMATION NEEDS IDENTIFIED BY SURVEY RESPONDENTS	**Not Sure**	**Not At All Useful**	**Slightly Useful**	**Moderately Useful**	**Useful**	**Very Useful**	**Useful + Very Useful**		**Additional Details**	**How Would Information Be Used?**
	Analyze the viability of small riparian/spring micro-habitats under future climate conditions.	*Not Applicable (these information needs were added by survey respondents so they were not available for other respondents to rate for their usefulness)*						*N/A*		*Not Applicable (these information needs were added by survey respondents and there was no option to indicate additional details or how the information would be used)*	
	Analyze anticipated human developments and how they are likely to impact water supply for streams, reservoirs, fisheries, and other wildlife.										
	Identify and provide habitat for species in peril in other states at lower elevation that may seek refuge in Wyoming as the climate changes.										
	Develop and incorporate a metric of climate vulnerability into WY's Species of Greatest Conservation Need status assessments.										
	Identify practices to maintain Species of Greatest Conservation Need that are vulnerable to climate change, and identify priority habitat areas where actions should be taken.										